18 QUESTIONS and ANSWERS ABOUT RADIATION

UNITED STATES ATOMIC ENERGY COMMISSION

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Washington 25, D.C.

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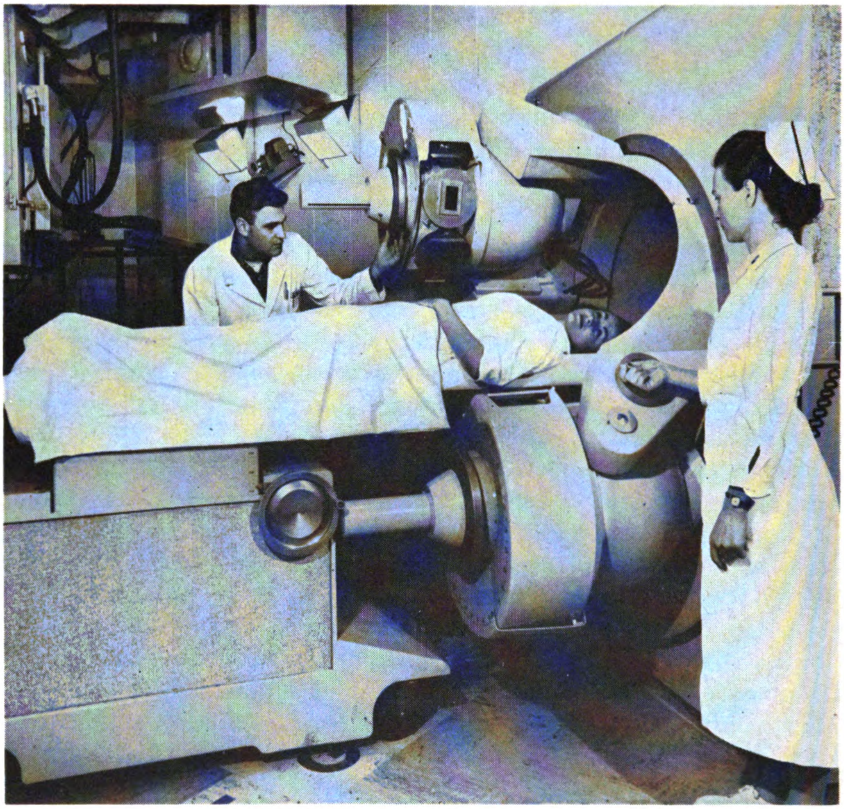
FOREWORD

THE ATOMIC ENERGY COMMISSION receives frequent requests for information about nuclear radiation and radioactivity presented in brief and nontechnical form. This booklet answers some of the more frequent questions on this subject.

More detailed information about these subjects has been published elsewhere. "Living with Radiation, The Problems of the Nuclear Age for the Layman," is available from the Superintendent of Documents, Washington 25, D.C., for 45 cents. "Radioisotopes in Science and Industry," Superintendent of Documents, $1.25, describes some of the benefits of using radioisotopes and radioactivity, and how their use is controlled for the protection of the public. The Commission's "Annual Report to Congress for 1959" contains a 90-page section dealing with "Management of Radioactive Wastes," which has been reprinted separately, and is available on request from AEC, Office of Public Information, Washington 25, D.C. "Selected Materials on Radiation Protection Criteria: Their Basis and Use," presented before the Joint Committee on Atomic Energy of the Congress, May 1960, may be purchased from the Superintendent of Documents for $3.75, and "The Nature of Radioactive Fallout and Effects on Man," (3 parts) presented before the Joint Committee in May–June 1957, is similarly available for $6.90. "Fallout from Nuclear Weapons Tests," (3 vols.) presented before the Joint Committee in May 1959, which includes updating of the 1957 hearings, is available for $7.25.



Serving Medical Science. Radioisotopes are not only proving a useful "tool" for medical research but are also being used in the diagnosis and treatment of human ailments. The gamma rays of radioactive cesium and cobalt, for instance, have proved useful in treatment of cancer. The photo shows the cobalt teletherapy unit at the Oak Ridge Institute of Nuclear Studies as it would be used in treating a cancer patient. The radiation, beamed through the openings in the radioisotope source holder (shown above patient), pass into the body to irradiate and destroy cancer cells which are more sensitive to radiation than are normal cells. Cancerous and tumorous growths may also be treated by implanting small quantities of radioisotopes within the body. In diagnosing an ailment, specific radioisotopes or isotope-labeled substances which show an affinity for certain organs or tissues of the body are administered to the patient. Then, through sensitive detection instruments which measure the amount of radiation emitted, the movement of the "labeled" compound within the body, or its concentration in certain areas, can be observed. Radioisotopes have also given the medical scientist a powerful new method for investigating the normal body processes. The radioactive form of many elements which are naturally present in the body system can be used to determine more effectively the role that particular element, and the substances into which they enter, play in the life process.

1. *What Is Nuclear Radiation?*

Nuclear radiations are types of energy that occur naturally in this world we live in, just as do other more familiar radiations such as light, heat, radio waves, and X-rays. General interest in nuclear radiations is comparatively new, and our unfamiliarity with the term and what it means may make these particular radiations seem mysterious, just as electricity once was mysterious to most people. We now know electricity as a familiar and indispensible servant of mankind; it has been controlled and put to work. Nuclear radiation, likewise, is being controlled and put to work for man's good. Handled carelessly, however, nuclear radiation, like electricity, can be destructive.

Nuclear radiations are forms of what we call atomic energy. The term designates the radiations that originate in the nucleus or heart of an atom. Atoms are the smallest possible units of the chemical elements that are the building blocks of our universe. Oxygen, hydrogen, carbon, and uranium are some of those building blocks, and they exist as atoms or combinations of atoms. Pure water is made up of oxygen and hydrogen; carbon occurs in coal, in sugar, and, in fact, in all living things. No one has even seen an individual atom. The smallest speck of coal that can be seen through a good optical microscope—a speck just visible when magnified about 2,000 times—contains something like a billion atoms of carbon and other elements.

Small as the atom is, it is made up of various parts—the nucleus that contains minute particles called *protons* and *neutrons*, and an outer shell made up of other particles called *electrons*. The nucleus carries a positive electrical charge; under normal conditions, the electrons carry an exactly balancing negative electrical charge. The nucleus and the electrons are bound together by what are called electrostatic forces—the same force that enables a glass rod, rubbed with silk, to pick up a scrap of paper.

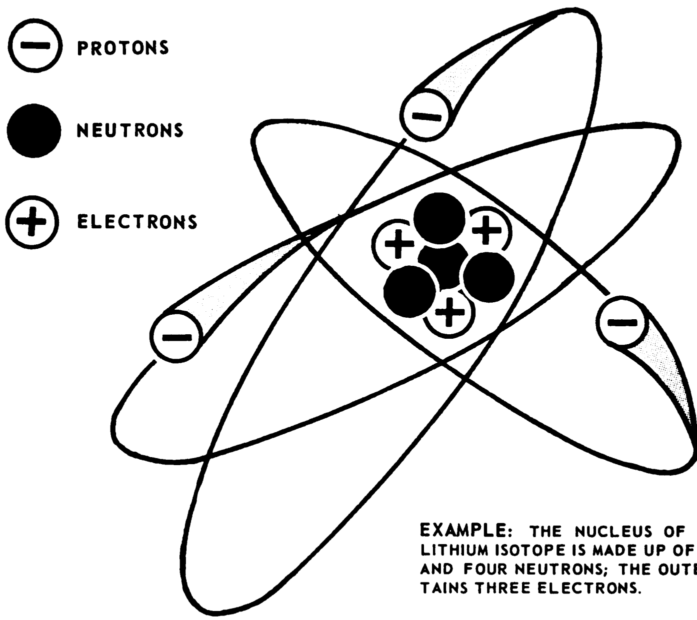
As electrons are bound to the nucleus of the atom, so are the particles within the nucleus—the protons and the neutrons—bound to each other by different and more powerful forces. These forces within the nucleus work toward a strongly stable balance. The process by which the nuclei of atoms work toward becoming stable is to get rid of excess energy. Unstable nuclei may emit a quantity of energy, or they may emit a particle. This emitted atomic energy or particle is what we call a nuclear radiation.

Most atoms are stable; all ultimately become stable, although some may take millions of years to reach their ultimate stable state. Most

atoms of carbon, for example, have 12 particles in their nuclei—6 protons and 6 neutrons. Carbon of this kind is stable, and not radioactive. It is a stable *isotope* of carbon. But carbon also has an unstable isotope—carbon 14—which has 6 protons and 8 neutrons in its nucleus. Carbon 14 is radioactive; it is a *radioisotope* of carbon. Each carbon 14 atom in time throws off a tiny particle of nuclear radiation as the nucleus works to attain a stable condition.

One isotope of uranium that occurs in nature is unstable in a different way. This is the isotope known as uranium 235 because it has 235 particles in its nucleus—92 protons and 143 neutrons. If another neutron is added to the nucleus of an atom of uranium 235, the nucleus becomes so unstable that it not only ejects radiation, it

AN ATOM and ITS PARTICLES



EXAMPLE: THE NUCLEUS OF THE ATOM OF A LITHIUM ISOTOPE IS MADE UP OF THREE PROTONS AND FOUR NEUTRONS; THE OUTER PORTION CONTAINS THREE ELECTRONS.

breaks into two large fragments, releasing a great deal of energy which turns into heat energy. This is the process which we call *atomic fission* and which we use in *nuclear reactors*, or atomic furnaces, for generating electricity. Two other isotopes of elements are known to have this same capability of fissioning when they capture another neutron. Uranium 233 is one; plutonium 239 is another. Fission is the reaction that takes place also in the explosion of nuclear weapons. In weapons the reaction takes place very rapidly in an uncontrolled way, whereas in nuclear reactors the rate of the reaction is under strict control. Similarly, gasoline can explode, but also can be burned in a stove or in an automobile engine.

Another type of nuclear reaction is called *fusion.* It is the opposite of the fission reaction. In fusion, two lighter atoms—usually isotopes of hydrogen—are forced to combine into a heavier atom, whereas in fission a heavy atom is made to divide into smaller atoms.

The fusion reaction, like fission, results in a great release of energy. It is the reaction that takes place in the explosion of what is called a hydrogen weapon (H-Bomb). Another term applied to this reaction is a *thermonuclear reaction.* This is because a great deal of energy has to be added to the lighter atoms to make them combine, and this energy usually is added in the form of heat. "Thermo" is a prefix that means heat.

The temperatures necessary to cause fusion are much higher than the 10,000-degree surface heat of our sun. Certain kinds of thermonuclear reactions apparently go on all the time in the sun, and are the source of the sunshine and warmth that make possible our life on earth. Several countries of the world, including our own, are carrying on research in an effort to tame the fusion reaction—in effect, to create a tiny, controlled sun on earth—in order to use this energy as a source of electric power.

2. *What Good Is Atomic Energy?*

People began to put nuclear radiation to work soon after they began to understand how it could be used. Radiation from radium is used, for example, to treat certain kinds of cancer. The X-rays used in medicine are not nuclear radiations, since they come from the outer part of the atom instead of from the nucleus, but they behave like certain nuclear radiations and can have the same kind of effects on people. X-rays are used, for example, to find out about infected teeth, to help doctors in setting broken bones, to give doctors information about many things that may be wrong with people, and to treat certain diseases. Radiations from some radioisotopes produced by the Government are being used in medicine in some of the ways that X-rays are used. They also are being used in industry instead of X-rays; for example, to detect flaws in metal.

One great use of radiation and radioisotopes is in scientific research. The Government manufactures radioactive forms of many elements that are not naturally radioactive. Because these radioisotopes give off nuclear radiation, the specific atoms so "labeled" can be identified by means of instruments wherever they go, and in any chemical compound they enter, even in living plants or animals. In this way radioisotopes provide scientists with a new tool which has been called the greatest aid to science since the invention of the microscope.

Working with these tools, scientists have found out many things about our bodies, about plants, and about chemical and physical reactions, and industrial products and processes, that previously it

Building a Strong National Defense. The combination of atomic energy and the submarine has produced a vessel that is a bulwark of our national defense. The nuclear-propelled submarine can perform feats that are bounded only by human endurance. Nuclear submarines have girdled the globe while submerged and traversed the North Pole beneath the ice. They can travel faster under water than on the surface, and fire ballistic missiles from the ocean depths. One loading of fuel will last for many months. The nuclear submarine can stay submerged for months at a time because its atomic reactor does not require air to operate, as other engines do, and science has perfected the means of re-energizing used air for human consumption. The photo shows the U.S. Navy's first nuclear submarine, the *USS Nautilus*. Launched in 1955, the *Nautilus* traveled 62,560 nautical miles, 36,498 of them while fully submerged, on its first loading of nuclear fuel. To duplicate this performance, a conventionally powered submarine of the same size would have required more than 2,000,000 gallons of diesel fuel—enough to fill 217 railroad tank cars making a train more than 1½ miles long. The initial fuel core was taken from the *Nautilus* early in 1957, before its energy had been expended, for studies leading to improved fuel loadings for other nuclear submarines. In May 1959, when the second fuel loading was removed from the *Nautilus*, the vessel had completed 153,886 nautical miles, of which 115,383 had been traveled while completely submerged. The Navy also is constructing surface ships which will be nuclear-propelled. (U.S. Navy photo.)

was impossible, or extremely difficult, to learn. Through experiments with radioisotopes, scientists are learning how plants extract foods from the soil, and how they use them: how plants use sunlight to produce the plant substances that are the basis of all life on this planet. It is this use of sunlight by plants that helps provide all the food we eat, either directly or by providing food for fish or farm animals. Agricultural scientists are learning ways to improve the use of fertilizers, and to destroy insect pests. This knowledge may lead to ways of increasing the world's food supplies.

Doctors may use radioisotopes to locate and define certain cancers or brain tumors so that they can be treated or accurately removed. Certain radioisotopes also are used to treat a limited number of diseases.

Other scientists and engineers are using radioisotopes to study problems of sewage treatment, of preventing "smog", of preserving food, of improving various industrial products, of testing foods to make sure all contamination is removed, and in hundreds of other ways.[1]

Nuclear reactors are being used, instead of diesel engines, to generate electricity and power for the new atomic submarines and other vessels of the United States Navy. Submarines driven by atomic energy are able to stay under the water for much longer periods of time than submarines powered by any other fuel, because reactors do not require oxygen to operate as other power plants do. They have traveled under the ice cap to the North Pole, and around the world beneath the surface of the oceans. These submarines would be extremely important to the defense of the United States in case of war.

Atomic bombs, atomic artillery shells, and missiles using atomic warheads—all using the nuclear fission or fusion process—are basic elements of the strength of the Armed Forces of the United States.

Fission is being used to produce electricity for use in homes and in factories. The electricity it manufactures is exactly the same as that generated by using water power, or by burning coal, or oil, or gas. Atomic energy provides the heat that runs the turbines that make electricity. The Department of Defense is planning to use atomic energy for power and for heat in remote regions such as Arctic outposts. Atomic energy may be used to supply power and heat for our scientific bases on the Continent of Antarctica.

As a source of almost limitless energy and as a new tool for science, atomic energy and nuclear radiation are opening many new paths of progress for the world.

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[1] Many of the accomplishments and new benefits being sought through the use of radioisotopes are described in a special report of the Atomic Energy Commission, "Radioisotopes in Science and Industry", available from the Superintendent of Documents, Washington 25, D.C. January 1960, $1.25. The regular reports of the Atomic Energy Commission to Congress also give more information.

3. *What Are the Different Kinds of Nuclear Radiation?*

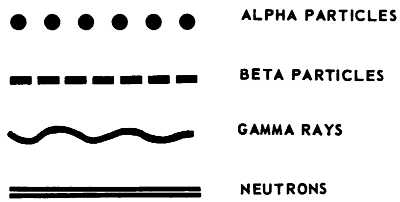
The four principal kinds of nuclear radiation are alpha particles, beta particles, gamma rays, and neutrons.

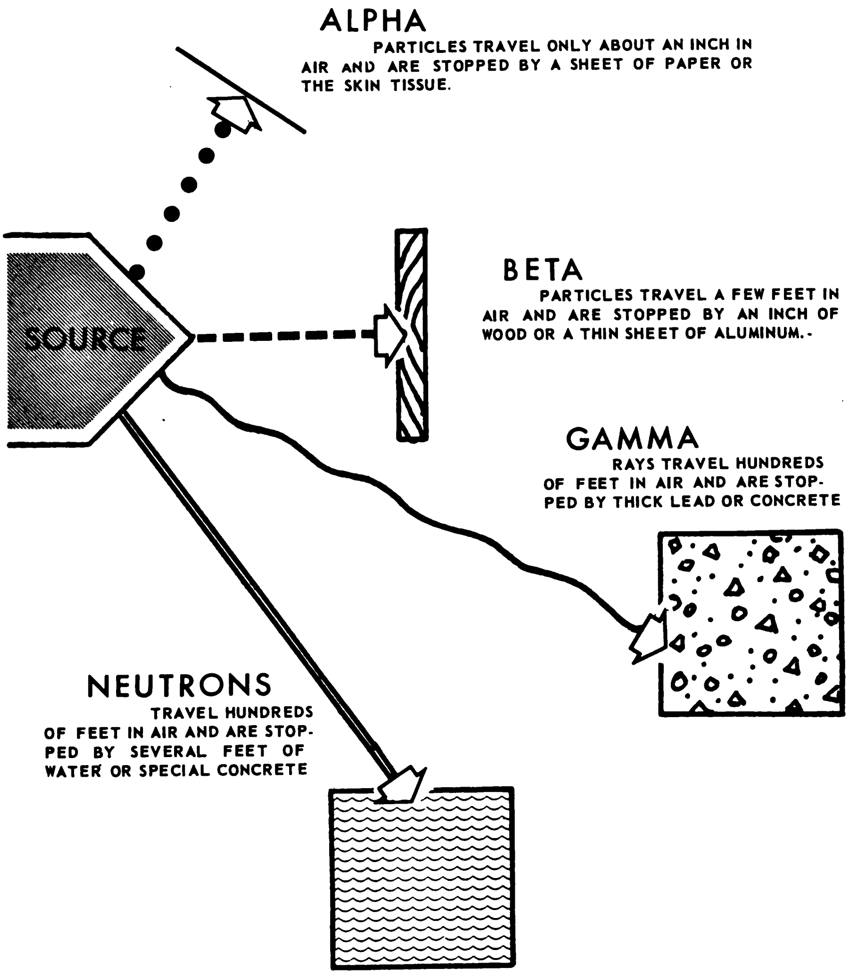
Alpha particles are emitted by heavy radioactive elements such as uranium, thorium and radium. Each alpha particle is made up of two protons (each carrying a positive electrical charge) and two neutrons—the tiny particles that make up the nuclei of all atoms. Tiny though alpha particles are—a hundred billion, billion of them would be no larger than the head of a pin—they are the largest nuclear particles. They have very little power of penetration. A sheet of paper will stop them, for example, and they cannot damage the tissues of the body except when a substance emitting them remains in direct contact with tissue for a long time. In that case, the radiation could cause considerable damage or result in functional disease. Alpha-emitting substances are used on the dials of watches and clocks or airplane or other instruments so that they are self-luminous and can be read in the dark.

Beta particles are thrown off by many radioactive materials—radioactive carbon 14 and radioactive strontium 90, for example. Beta particles have much less mass than alpha particles (the mass is about 1/7200th that of an alpha), and they carry a negative electrical charge. They are more penetrating than alphas, and those betas that have the highest energy can travel several yards through the air, or penetrate up to a third of an inch or more of body tissue, depending on their energy. Overexposure to beta particles can cause severe skin burns. Materials that give off betas can cause serious damage or functional disease as can alpha-emitting substances if too much gets inside the body and remains there. Substances that emit beta particles—such as radioactive hydrogen, or tritium, recently made available by the Commission—are used in self-luminous dials. Beta-emitting substances also are used for industrial gages that measure the thickness of materials being produced, for medical treatment of certain tumors or skin lesions, and in many scientific studies.

Gamma rays and *X-rays* are not particles like alphas and betas, but are invisible electromagnetic waves of energy like light, and radio and television waves. Gamma rays are essentially the same as X-rays. Those with the highest energy are the most penetrating. Gamma rays have no electrostatic charge, and can travel hundreds of feet through the air, or penetrate for many inches through solids (thick lead, concrete, or earth barriers are effective protection—the thicker and denser the substance, the more effective is the protection). Exposure to large amounts of energetic gamma rays can cause severe damage. Doctors use gamma rays, or gamma emitting substances, to help in diagnosing sicknesses, or to treat certain diseases. Industry uses gamma ray generators in place of X-ray machines in detecting flaws in metal

4 KINDS of NUCLEAR RADIATION





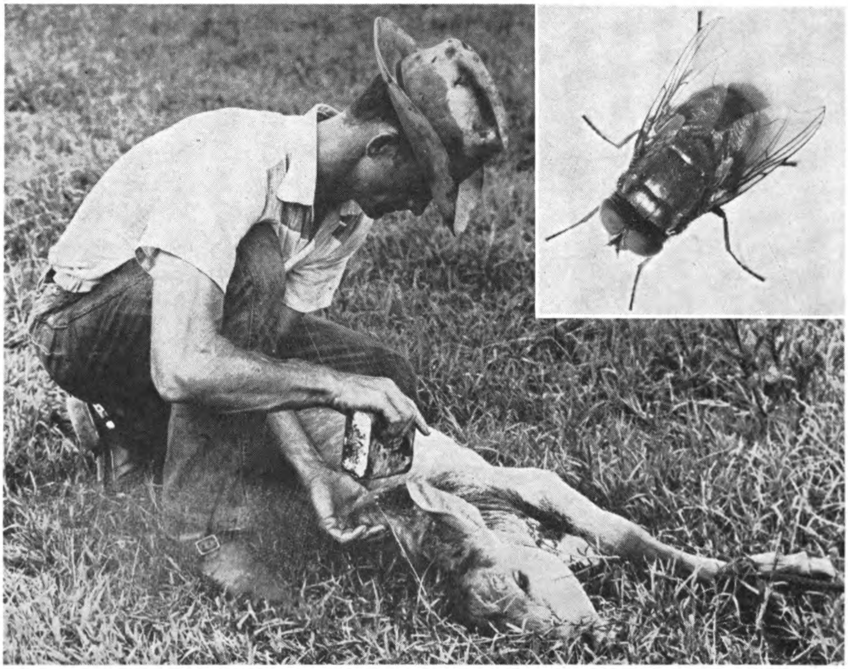
products, and for measuring the density of various products to assure quality or to control various processes. Gamma emitting radioisotopes are used in scientific laboratories throughout the world to find out more about the world in which we live and to put products to better use for us. These rays are also useful in insect control or eradication programs.

Neutrons are nuclear particles, with no electrical charge. Their mass is about the same as that of a proton. They have no electrostatic charge and can travel hundreds of feet through air, or penetrate many inches through solid matter. They are best stopped by elements or materials containing large amounts of hydrogen such as water and special concretes. Neutrons are of no importance in considering the emission of nuclear radiation by materials under natural conditions. They are produced primarily in nuclear reactors which are used for research or to produce power, and also in a few scientific and industrial instruments designed for the specific purpose of producing neutrons. Neutrons are essential to the operation of nuclear reactors, since it is the neutron which splits (fissions) the atoms of uranium and thus leads to generating the heat used to produce electricity. Neutron-producing instruments are used to measure the density of soil and to assist in logging strata through which an oil well is drilled, and for other purposes. Neutrons also are used in a scientific process called "neutron-activation analysis" which makes it possible to measure infinitesimal traces of certain elements in a substance. For example, contaminants in steel may be rendered radioactive by exposure to neutrons, and hence may be measured by the type and energy of the radiation they emit. Neutron beams from a reactor also have been used experimentally to treat brain tumors.

4. *What Is Nuclear Radiation Like?*

When the unstable nucleus of an atom ejects a particle or ray, the particle or ray carries with it some of the energy of the nucleus. This energy may be expressed either in radiation like X-rays, or in the speed of movement—the velocity—of the radiated particle. When the particle or ray strikes an atom of another substance—for example, an atom of a gas in the air—it can disturb the electrical balance of the atom, which normally makes the atom electrostatically neutral. If the nuclear radiation knocks loose one or more of the negatively charged electrons from an atom, the atom is left positively charged. Each of the two—the positively charged nucleus and the negatively charged electron—is called an *ion*. Nuclear radiation is called *ionizing radiation* because it produces these *ion pairs*.

Except in extremely large quantities, nuclear radiation cannot be detected by any unaided human sense. Ordinarily, it cannot be seen or felt, smelled or tasted or heard, any more than a television or radio



Eradication of Agricultural Pests. **Atomic energy is being used to help reduce the millions of dollars worth of damage caused annually to the agricultural industry by insect pests. One example is the eradication of the screwworm fly (shown above) from the southeastern United States in an 18-month effort that cost less than $10 million. The fly formerly cost cattlemen of the Southeast alone an estimated $20 million a year in animals killed, deformed or made more susceptible to disease, in loss of weight and ruined hides, and in the cost of periodic checking for infestation and treatment of each animal. About twice the size of the common housefly, the screwworm fly has a metallic-colored body and red head, and is a warm-climate insect. It formerly wintered in Florida and migrated into the adjoining states during the summer. The female fly mates only once during her life, laying from 250 to 3,000 eggs in the open, untreated wounds of cattle. The larvae, emerging from the eggs, feed on the living flesh and a badly-infested, full-grown animal can die within 10 days as a result. The eradication campaign involved the release of screwworm flies made sterile by gamma irradiation and which, upon mating with native flies, produced infertile eggs. Some 50 million flies a week were reared under controlled conditions, sterilized by exposure to cobalt 60, and released from planes. The project, started in January 1958, eliminated the over-wintering population of the screwworm fly east of the Mississippi within 18 months. The screwworm fly still is a scourge to the livestock of the southwestern United States where its eradication would be much more difficult since there are no natural barriers, such as the Florida coastline, to the fly's migration from south of the Mexican border. It is native to Central and South America. (Department of Agriculture photos.)**

wave can be detected without an instrument built for that purpose. As with television and radio waves, various kinds of nuclear radiation can be detected and measured by the use of instruments. The presence of a highly energetic beam of radiation in water can be observed because it creates a blue-white glow by what is known as the Cher-

enkov effect. Like lightning, radiation, because of its ionizing effect, can create ozone from oxygen in the air, and this can be smelled.

Another key fact about nuclear radiation is that the amount of radiation discharged by any quantity of a single radioisotope—whether natural or man-made—becomes less and less as time goes on. The rate at which this happens is different for each particular radioisotope, but the reason it happens is the same for all—a process called *radioactive decay.* In this process, the radioactive or unstable atoms, one by one, discharge their radiation as they move toward becoming stable, nonradioactive atoms. When they discharge radiation, they turn into different atoms—either a different isotope of the same element or an atom of an entirely different element. In a quantity of radioactive carbon 14, for example, some of the atoms are always discharging their radioactivity and turning into atoms of nitrogen 14 which is not radioactive. Each carbon 14 atom can discharge radiation only once.

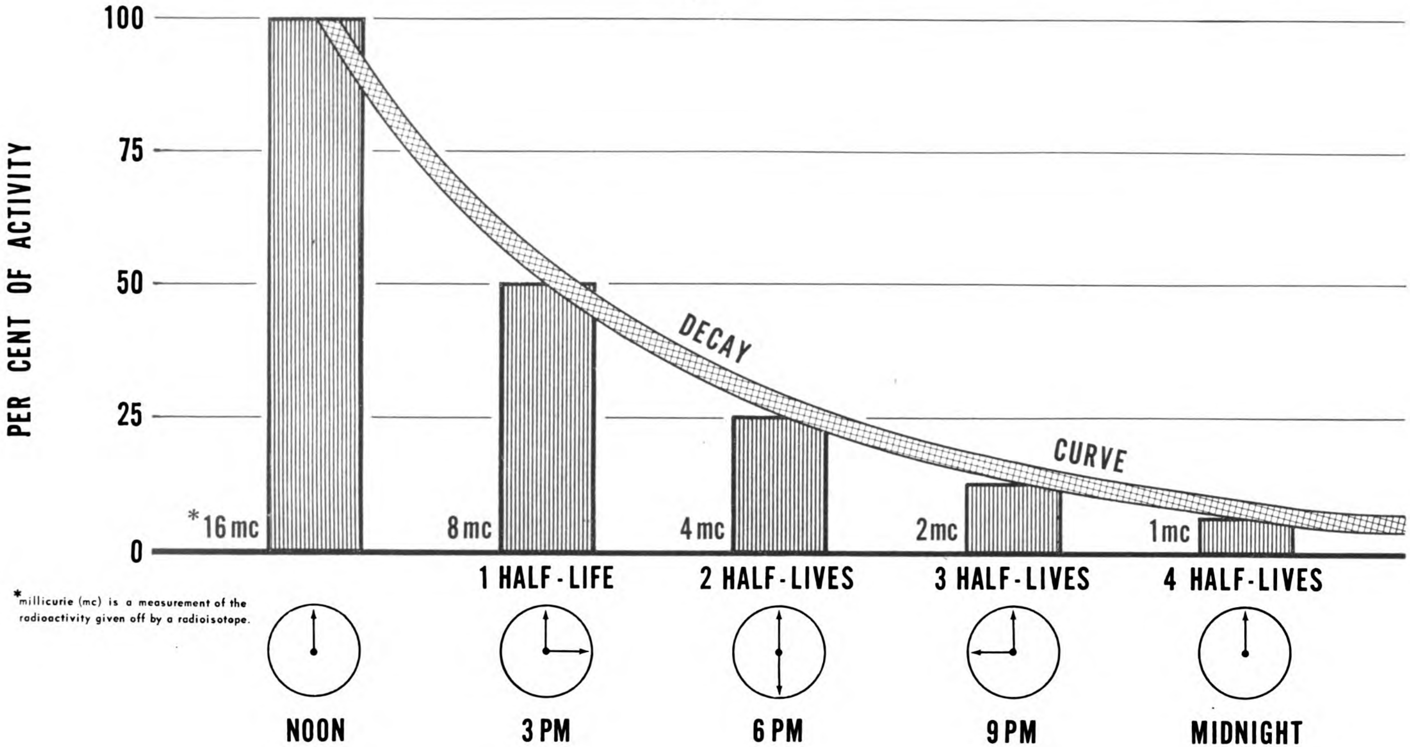
Not all decay patterns of radioisotopes lead directly from radioactive atoms to stable atoms. Each radioisotope has its own pattern. For example, when atoms of radioactive strontium 90, one by one, discharge their radiation they become atoms of radioactive yttrium 90 and these atoms, discharging radiation in turn, become stable zirconium 90. A few radioactive materials like uranium and thorium turn into a long succession of other radioactive materials, each atom of one radioactive material changing into an atom of another radioactive material, and then into an atom of still another radioactive material. Radium is one of the decay products of uranium, and radon gas is the first decay product of radium.

The length of time that any quantity of a particular radioisotope will take to discharge half of its radiation and thus decay is measured in what scientists call the *half-life* of the material. During a period of time, different for each material, any quantity of a particular radioisotope will decay into half its original amount, thus reducing its radiation by half, and this period is the half-life for that particular radioisotope. During a second equal period of time, the remaining amount of the radioisotope will again decrease by half, and this process will continue at the same fixed rate. In two half-lives, then, the radioisotope will be reduced by 75 percent of its original amount, and its radioactivity will be similarly reduced; in three half-lives, 87½ percent; in four half-lives, 93¾ percent, and so on. In other words, at the end of four half-lives, any amount of a particular radioisotope will be reduced to one-sixteenth the original amount, and the level of its radioactivity will similarly be one-sixteenth the original amount. (See chart for the decay pattern of a radioisotope with a half-life of 3 hours.)

Some radioisotopes are so unstable that they have a half-life of only fractions of a second; some remain radioactive for only a few

RADIOACTIVE DECAY PATTERN

(IN A HALF-LIFE PERIOD, THE RADIOACTIVITY IS REDUCED BY ONE-HALF. THE CHART IS FOR A RADIOISOTOPE WITH A 3-HOUR HALF-LIFE.)



*millicurie (mc) is a measurement of the radioactivity given off by a radioisotope.

weeks; some require tens of years, or even millions of years, to discharge half their radioactivity. For all practical purposes, nothing that can be done to a radioactive material will either speed up or slow down its natural rate of radioactive decay.

Some examples of patterns of radioactive decay, and the half-lives of the materials, are given in the following table:

Original radioactive material	*Half-life*	*Decay product radioactive material*	*Half-life*	*Decay product stable material*
Iodine 131	8 days→	none→		Xenon 131 (99%)
Potassium 40	1.4 billion years→	none→		Argon 40 or Calcium 40
Carbon 14	5,700 years→	none→		Nitrogen 14
Strontium 90	28 years→	Yttrium 90	64 hours→	Zirconium 90
		↓		
Radium 223	11.2 days→	Radon 219	3.92 sec.	
		↓		
		Polonium 215	0.00183 sec.	
		↓		
		Lead 211	3.61 min.	
		↓		
		Astatine 215	0.001 sec.	
		↓		
		Bismuth 211	2.16 min.	
		↓		
		Polonium 211	0.005 sec.	
		↓		
		Thallium 207→	4.76 min.→	Lead 207

5. *Where Does Radiation Come From?*

Nuclear radiations are a natural part of man's environment, just as are the sunlight and the earth's magnetic fields. We have always lived in an environment that includes these natural radiations. In addition, we have created new sources of radiation as we have explored nature and hunted for ways to improve our control and use of nature.

Natural radiation comes both from the earth and from the sky. Such minerals as uranium and thorium, and substances associated with them, exist everywhere in the earth. Granite rock contains both uranium and radium in small quantities, as do all soils formed by break-down of granitic rocks. It has been estimated, for example, that if men were to remove a foot of topsoil from a square mile of the earth's surface in the midwestern part of the United States, they would find that the soil—weighing something like 2 million tons—would contain about 3 tons of uranium and one twenty-eighth of an ounce of radium. Naturally radioactive chemical elements are present in all living things because these elements are absorbed by plants from the earth or are dissolved into ground water just as stable elements are. Both radium and thorium produce the radioactive gas, radon, which is present in small amounts in the air that people breathe. Radioactive carbon is present in all living things, and also in the air we breathe. It is made radioactive by the impact of cosmic radiation—nuclear particles of very high energy, usually called cosmic "rays", which strike the earth's atmosphere from outer space. This same cosmic radiation also contributes by direct impact to the amount of radiation to which we are exposed.

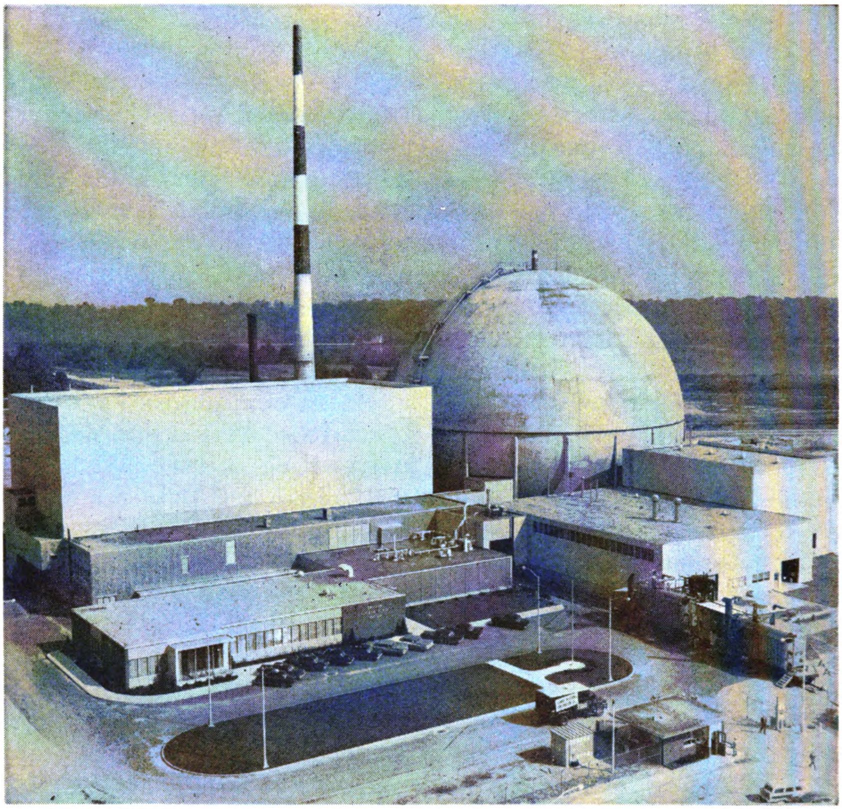
Thus, natural sources of radiation exist in the earth, in the air, and in the water, and also find their way into living things through their food. This is true of both plant life and animal life. This fact that all living things have absorbed radioactive material throughout history enables scientists to measure the age of human relics and animal and plant remains, and helps to unravel the unwritten history of the earth. They make use of the fact that human beings, animals and plants absorbed radioactive carbon as long as they were alive; after that, the radioactive material they had absorbed while alive gradually underwent radioactive decay. By measuring the extent to which radioactive decay has occurred, scientists can tell how long ago the man, animal, or plant lived. By measuring the radioactivity of a "solar ship" placed near the tomb of an Egyptian pharaoh, we have been able to date his death. By testing trees killed by glaciers, we have dated the last American ice age. Carbon-dating, as it is called, helped establish the authenticity of the recently discovered Dead Sea Scrolls which contained early versions of chapters of the Bible. This method is chiefly useful in dating remains up to about 25,000 years old; the radioactivity of carbon 14 in older remains is too small to measure with a high degree of accuracy.

The first *man-made radiation* used in any quantity came from X-ray machines used in medicine and, later, in industry. Other kinds of radiation have been created by man through the use of nuclear reactors, or of the particle accelerators known as "atom smashers." As a consequence of the uses of radioactivity and radioactive materials—from treating disease and producing power and testing weapons—wastes have been created, just as in many other scientific and industrial operations. The wastes created in atomic energy programs differ from the wastes from other industrial operations because they generally contain much more radioactivity. A later answer, No. 10, gives information about wastes. Separate booklets supply details about the wastes and how they are controlled.[2] Their release is regulated and inspected by the Federal Government.

6. *Is Nuclear Radiation Harmful?*

Exposure to excessive amounts of nuclear radiation can cause injury, sickness, or functional disease, and exposure to extremely large amounts of nuclear radiation can cause death. Many scientists believe that people experience some biological effects from even small amounts of nuclear radiation, but they have been unable to detect or to measure any immediate biological impairment from very low exposures. Of course, whatever harm people may receive from life-

[2] "Management of Radioactive Wastes." AEC Annual Report to Congress for 1959, pp. 289-382, Superintendent of Documents, Washington 25, D.C., $2.00.



Conservation of Natural Resources. **Photo above shows the world's first large-scale, privately financed commercial plant that uses atomic energy to produce electricity—the Dresden (Illinois) Nuclear Power Station of the Commonwealth Edison Co. The 180,000 kilowatt station, located about 40 miles southwest of Chicago, began producing electricity at full power in mid-1960—enough electricity to supply the normal needs of a city of about 200,000 persons. The atomic reactor is located in the sphere and generates heat which is used to create steam. The steam, in turn, drives the electricity-producing turbogenerators which are in the tall, square building. The tall stack—there is no smoke from an atomic power plant—is used to disperse the ventilating air from the buildings and the small amounts of waste gases that accumulate during operation of the plant. (Photo courtesy of General Electric Co.)**

time exposure to low levels of natural radiation has been experienced throughout the world's history. The advent of man-made radioactivity has increased the levels to which people are exposed, and has created concern about the effects of that increase.

The effects that exposures to radiation have on people depends on various things:

First, of course, on the amount and rate of radiation exposure.

Second, on the kind of radiation—whether it is penetrating radiation like gamma-rays and X-rays, or relatively nonpenetrating like alpha particles.

Third, the tissue exposed, which depends in turn on the source of the

exposure—whether the radiation comes from outside the body or from some substance inside the body, and

Fourth, on the kind of radioactive material involved, its radioactive and chemical nature, and its biological path if taken into the body.

A relatively small amount of one substance inside the body—radium, for example—might be extremely harmful since it naturally travels to a sensitive part of the body, and remains there, giving off its heavy radiation at close range. A relatively large amount of another substance even inside the body—pure uranium, for example—might not be a serious matter from the standpoint of radiation. Normal uranium inside the body is more dangerous as a chemical poison than it is as a source of radiation, since relatively large quantities are required to cause severe radiological damage.

Over the years, and especially within the last half-century, we have increased the amount of radiation to which we are exposed whenever the benefits appeared to outweigh the risk. Exposure to large amounts of X-rays, for example, can cause injury, sickness, and death, but doctors may when necessary, use heavy doses of X-rays under carefully controlled conditions—dosages large enough to cause mild radiation sickness—in treating some diseases and conditions.

The Atomic Energy Commission, and the wartime developer of atomic energy—the Manhattan Engineer District of the U.S. Army Corps of Engineers—have worked with amounts of radiation far greater than the world has ever known before. They have controlled this radiation and strictly limited exposures for the workers. The Commission has had safety records which show fewer man-days lost from injuries than the national average for all manufacturers, and very, very few of these injuries resulted from radiation. Many employees in the Federal Government's atomic energy plants work in areas where radiation is a part of the industrial environment. These employees are carefully safeguarded, as is the public living in the vicinity of these plants, and exposure is kept to levels which radiation experts have estimated are acceptable. There is no evidence, except in rare cases of heavy accidental exposure, that these workers have suffered impairment as a result of radiation.

The report of the National Academy of Sciences-National Research Council[3] has this to say about the protection of the public:

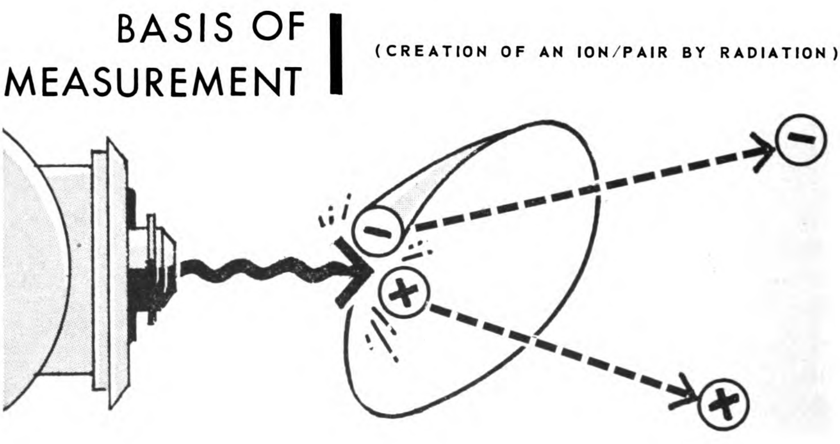
> Despite the existing gaps in our knowledge, it is abundantly clear that radiation is by far the best understood environmental hazard. The increasing contamination of the atmosphere with potential carcinogens (nonradioactive cancer-causing factors), the widespread use of many new and powerful drugs in medicine, and chemical agents in industry, emphasize the need for vigilance over the entire environment. Only with regard to radiation has there been determination to minimize the risk at almost any cost.

[3] Page 28, "Summary of Reports, The Biological Effects of Atomic Radiation—A Report to the Public."

7. *In What Units Is Radiation Exposure Measured?*

Some key units used to measure radiation exposure and nuclear radioactivity are the *roentgen*, the *rad*, the *rem* and the *curie*. Explanations of the meaning of these units and their fractions are given in the following paragraphs.

ROENTGEN (*r*)—This is a unit of exposure dose which is a measure of the ability of X-rays or gamma rays to produce ionization in air. Ionization is the creation of ion pairs—positively and negatively charged parts of atoms—by the impact of radiation on those atoms. One roentgen of radiation has the ability to produce an amount of ionization which represents the absorption of approximately 86 ergs of energy from radiation per gram of air. The number of roentgens is determined by measuring the amount of ionization with suitable devices. (Formally, one roentgen is an exposure dose of X- or gamma-radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit of electricity of either sign.)



EXAMPLE: An X-ray or gamma ray striking a hydrogen atom (one proton and one electron) in the atmosphere breaks the normal attraction that the positively and negatively charged ions have for each other and they whirl off separately as a pair of unattached ions. One roentgen of X-rays creates about 1.61 million ion-pairs. The electrically-charged particles, when striking the sides of a measuring device (the Gieger-Mueller tube, for instance), cause a disturbance the intensity of which can be used to determine the amount of nuclear radiation in the area.

MILLIROENTGEN (m*r*)—One thousandth of a roentgen.

RAD—This is not an abbreviation, but a term adopted in recent years. The rad is the unit of *absorbed dose*, and amounts to 100 ergs of energy imparted to matter by any ionizing radiation, per gram of irradiated material at the place of interest.

MILLIRAD (mrad)—One thousandth of a rad.

REM—This may be thought of as an abbreviation for *radiation effect*, man. Its meaning has undergone considerable change since first conceived. It now represents the absorbed dose of *any* radiation which has the same biological effect as a RAD of "standard" X-rays. (Since various radiations such as alpha, beta, gamma, rays and neutrons have different biological effects per RAD of absorbed energy, they are ascribed a "relative biological efficiency" or RBE. Using this concept, the number of REMS=RADS×RBE.)

MILLIREM (mrem)—One thousandth of one rem.

CURIE—A unit used to measure the rate at which radioactive material, or a combination of radioactive materials, is giving off nuclear particles. Actually it represents the rate at which radioactive decay is taking place in the material in terms of beta or alpha discharge; since each atom of each material discharges either of these particles only once (it may also emit a gamma ray), the curie is a measure of the rate of radioactive changes in the atoms. It has no direct relationship to the other units of measurements of exposure. A curie is equivalent to the number of atomic disintegrations occurring per second in a gram of pure radium and is defined as 37 billion disintegrations per second.

MILLICURIE (mcurie)—One thousandth of one curie: 37 million disintegrations per second.

MICROCURIE (mccurie)—One millionth of one curie: 37,000 disintegrations per second.

MICROMICROCURIE (mcmccurie)—One millionth of one millionth of a curie: 0.037 disintegration per second, or some 37 disintegrations in about 16 minutes.

8. *How Much Radiation Are People Exposed To?*

There is no single answer for all people throughout the world, or even throughout the United States, to this question.

Average exposure to radiation can be estimated for all people, for a nation, or for a locality at a specific time. Estimates have been made, for example, of the "normal" amount of natural radiation to which people in the United States are exposed on an average. At any particular place, however, the actual level of exposure may be higher or lower depending on such natural factors as the amount and kinds of radioactive material in the soil, water, and air, and also on altitude, since cosmic radiation is greater at high altitudes because the thinner air provides less shielding.

Whatever the local level of natural background radiation, this may be increased by what is called environmental contamination. Radioactive materials released to the environment as a component of in-

dustrial wastes may contribute to environmental contamination in some places. Another source of this contamination is a fallout—the debris from exploded atomic devices which falls gradually to the earth after being released to the atmosphere from nuclear weapons tests of the United States, the Soviet Union, and the United Kingdom. Accumulation of fallout may vary according to latitude, the rate of rainfall or snowfall, the season of the year, and exposure can vary with the diet of individuals.

Atomic energy workers, or medical and scientific workers with radiation, routinely accept certain levels of exposures. Other exposures to man-made radiation result from use of self-luminous instrument dials and television sets.

The largest single component of people's general average exposure in the United States is medical radiation: diagnostic or therapeutic X-rays, examination by fluoroscopes, use of radium, and radioisotopes of various kinds for treatment or diagnosis. In fact, when medical radiation exposure to individuals is averaged for the total population, this one source contributes more to average exposure than all other sources of radiation combined. For individuals, medical radiation exposure varies according to the part of the body X-rayed or treated, the purpose of the treatment, and the frequency and amount of exposures. For example, a chest X-ray would be equivalent to about 100 to 1,000 millirems exposure to the chest; a dental X-ray about 5,000 millirems per film to the jaw.

The following table gives the estimated average exposures of people in the United States each year from various categories of radiation.[4] The exposure is estimated in terms of millirem dosage to the testes and ovaries—a selective measurement often used in such calculations since the possibility of genetic effects in population groups is of particular interest.

The figures as given represent a middle-of-the-road approach. For most of the specific average exposures listed in the table, a rather wide range of higher and lower values can be found. Using lowest estimates in the various categories of radiation exposure would minimize total dose from radiation; equally, the highest estimates in each category would distort the true situation. The general proportion between the amounts of exposure attributed to natural radiation and the amount attributed to man made radiation, and between exposure from medical procedures and from other sources such as fallout, would be about the same, regardless of whether the higher or the lower totals were used.

[4] Sources: (1) Report of the United Nations Scientific Committee on the Effects of Atomic Radiation, New York 1958; (2) The Nature of Radioactive Fallout and Its Effects on Man, Hearings before the Special Subcommittee on Radiation, Joint Committee on Atomic Energy, May 27-29, June 3-7, 1957; (3) Radioactive Biology and Medicine—Selected Reviews in the Life Sciences, edited by Walter D. Claus, USAEC, presented at the Second International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1958.

ESTIMATED AVERAGE ANNUAL GONAD[1] EXPOSURES IN UNITED STATES

	Millirems
NATURAL SOURCES:	
A. External to the body:	
1. Cosmic radiation	28.0
2. From the earth	47.0
3. From building materials	3.0
B. Inside the body:	
1. Inhalation of air	2.0
2. Elements found naturally in people	21.0
Total, natural sources	101.0
MAN-MADE SOURCES:	
A. Medical procedures:	
1. Diagnostic X-rays	150.0
2. Radiotherapy X-ray, radioisotopes	10.0
3. Internal diagnosis, therapy	1.0
Subtotal	161.0
B. Atomic energy workers	0.1
C. Luminous watch dials, television tubes, shoe fluoroscopes, radioactive industrial wastes, etc	1.0
D. Radioactive fallout:	
1. External dose	3.0
2. Internal dose	1.0
Subtotal	5.1
Total, man-made sources	166.1
OVERALL TOTAL	267.1

[1] Testes and ovaries.

9. *What Are the Natural Sources of Radiation?*

The sources of natural radiation were stated in the answer to question 5—chemical elements in the air, earth, water, and food, which are naturally radioactive, or like carbon 14 and hydrogen 3 may be made radioactive by natural means, plus cosmic radiation. The more common chemical elements that are radioactive, besides uranium and thorium and their radioactive decay products, are potassium 40, ribidium 87, samarium 147, lutetium 176, and rhenium 187.

From the standpoint of their effect on man, these naturally radioactive materials are of two sorts: one, the materials that chiefly cause radiation which strikes the body from outside; the other, the materials that get into the body from the air, water, or foodstuffs. The Report of the United Nations Scientific Committee on the Effects of Atomic Radiation (New York, 1958)[5] grouped the natural elements according

[5] Op. cit, p. 15.

to these two categories, and according to estimates of the "normal" natural radiation dose per year to various parts of the body:

External Sources:	*Gonads* [1] millirems	*Bone* millirems	*Bone-marrow* millirems
Cosmic rays	28	28	28
Radiation from earth	47	47	47
Radiation from air	2	2	2
Internal Sources:			
Potassium 40	19	11	11
Carbon 14	1. 6	1. 6	1. 6
Radon-thoron	--------	38	0. 5
Approximate total	100	130	95

[1] Testes and ovaries.

10. *What Are the Sources of Radioactive Wastes?*

Some wastes are generated wherever radioactive materials are processed, created, or used—in industrial and Government operations, in nuclear reactors, in laboratories and hospitals. The management of all these wastes, their storage, disposal, or possible release, and the conditions governing such handling, are under Federal or State Government control.

Some of the radioactivity in wastes is natural, not man-made, radioactivity. For example, when uranium ore is milled and processed the wastes include a fraction of the uranium and radium normally present in the ores. The radioactivity per atom of these materials has not been increased, but the total radiation at that site is increased by concentration there of large amounts of the minerals.

These naturally radioactive wastes are required under law not to be discharged except in such a way that they enter streams at a rate that will assure adequate dilution; the concentration of radiation per volume of water must be kept low. The standard applied in this, as in other radioactive waste disposal, is that the concentration of radioactive materials must be such that the water can be drunk throughout a lifetime without the person who drinks it exceeding the total accumulation of specific radioisotopes which experts believe man can tolerate. Some uranium ore mills have exceeded the legal concentration, and have been directed to correct the situation which caused this to occur.

Manmade radioactive materials are created whenever nuclear reactors are operated (as described in the answer to the first question in this booklet). All Government-owned reactors, and all licensed reactors, must undergo thorough safety analysis and are inspected during operation for safety. The intensely radioactive material that reactors create normally is confined to the fuel elements of the reactor. Fuel elements are removed from the reactor when no longer

usable, and it is not until the fuel elements pass through a chemical separation plant (at present, only the Government operates such plants) that their material takes the form of liquid, highly radioactive, industrial wastes. The separation plants extract plutonium, and the process liquids later may be reworked to remove uranium or other valuable radioisotopes. The highly radioactive residues are stored in isolated underground tanks under Government control.

Some other wastes that are much less radioactive also may be generated at reactor sites. Radioactive gases or other products may be created in water, air, or other substance used to cool the reactor, or may occasionally leak into the coolant from ruptured fuel elements. Dilute wastes may be created in plant laundries where working clothes are washed, or in plant laboratories. All such wastes must be continuously monitored to measure their levels and concentrations of radioactivity. The wastes that may be released to the environment under regulated conditions are those which have low levels of radioactivity, those which can be rapidly and enormously diluted to authorized levels by water or air before leaving controlled premises, or those which can escape only very slowly into the environment.

Any exception to the regular standards governing release of wastes to the environment must be weighed in consideration of the specific material and conditions involved. For example, some types of wastes may be buried at sea and the requirement is that they must be within certain limits of radioactivity and thickly cased in containers to assure their sinking in deep water. However, a highly radioactive naval reactor structure was buried at sea after consideration of the specific case: the structure was of stainless steel that corrodes very slowly even in salt water, and the radioactivity can escape from the structure only by this slow corrosion. Some types of wastes are buried on land in reservations and regularly monitored. (At present, all such burial is on Government reservations and controlled by the Government.)

Much of the wastes that laboratories and hospitals generate are such items as experimental animal carcasses, excreta, broken laboratory glass, cleanup papers, and equipment contaminated by radioactive material. Liquid wastes are generated also, and their radioactivity may be very high or extremely dilute, and include both natural and manmade radioactivity. The various systems of control and waste management are geared to the potential hazards at the institution, and rigorously governed by Federal regulation and inspection.

The report of the National Academy of Sciences-National Research Council that was quoted earlier also states: "To date, radioactive waste operations have not resulted in any significant effect on the public, its environment, or its natural resources." [6]

[6] See p. 9, *op. cit.* p. 15.

Management of radioactive wastes is not treated in detail in this booklet. Separate publications, listed earlier, will provide answers to additional questions on this subject.

11. *What Is the Source of "Fallout"?*

The word *fallout* is used in a special sense in connection with detonation of atomic weapons: It includes the radioactive materials that nuclear weapon explosions release to the atmosphere and which remain radioactive long enough to fall out upon the surface of the earth.

In general, heavier particles fall to earth within a few hours after the explosion around the site of the explosion; lighter particles may be blown into the upper atmosphere and remain there for varying lengths of time—depending chiefly on how high they are blown—before falling out on the surface of the earth.

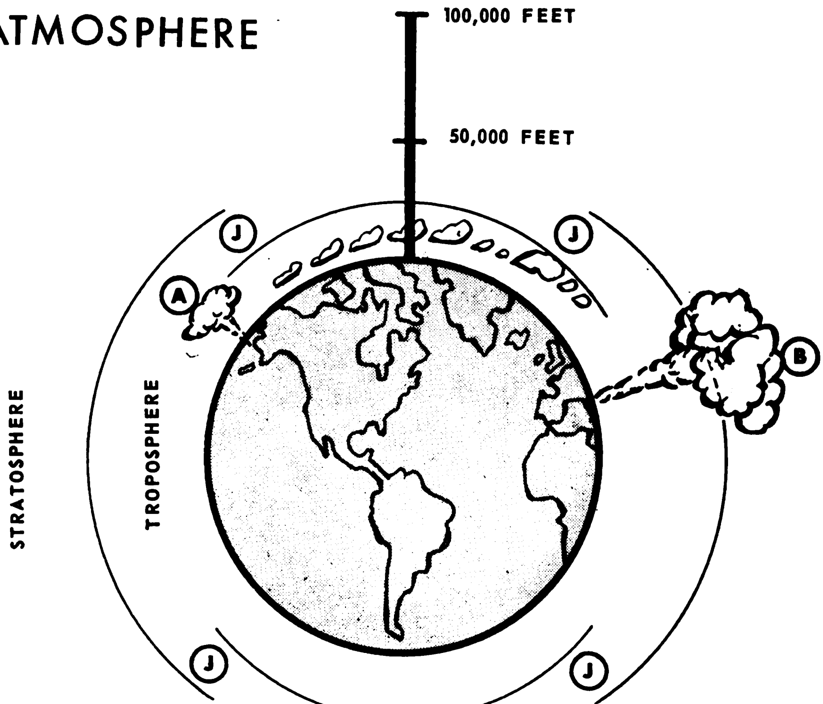
The heavier particles contain radioactive material present in the cloud of smoke and gas created by the explosion, and which condense on explosion-raised dust. Most of these particles fall downwind from the site of the test. How near the site they fall depends on their individual size, on weather conditions, and also on the size of the explosion that created them. If the explosion is small, and the wind light, they will descend near the site. Tests held by the United States have been planned in accordance with weather conditions and weather forecasts with a view to confining the heavy-particle fallout to safe areas.

Lighter particles may be carried by the wind to much greater distances before they descend to earth. How soon they descend also depends importantly on the size of the explosion that created them. If the particles are not blown higher than about 35,000 to 55,000 feet, most of them are washed out by rainfall within a few weeks. The part of the earth's atmosphere up to about 35,000 to 55,000 feet is known as the troposphere, the "weather zone"—the space in which clouds are formed, and from which rain and snow descend. The height of the troposphere varies with latitude and season of the year. For example, it extends to about 55,000 feet in the tropics, and to about 35,000 feet in polar areas. Particles in the troposphere may be carried all the way around the earth before they fall out, but they usually descend—chiefly in rain or snow—in about the same latitudes or zones of the earth's surface in which the explosion occurs.

If the explosion that creates the light particles is very large, a portion of the fallout is blown above the troposphere, and into higher regions of the earth's atmosphere—the stratosphere. When this happens, the light particles may remain in the atmosphere for months or years before they work their way down into the tropospheric "weather zone" and then are deposited on the earth. Material

blown into the stratosphere may fall out over any part of the earth's surface, but so far the highest levels have been measured in the Northern Hemisphere where most of the weapons tests have taken place.

THE EARTH'S ATMOSPHERE

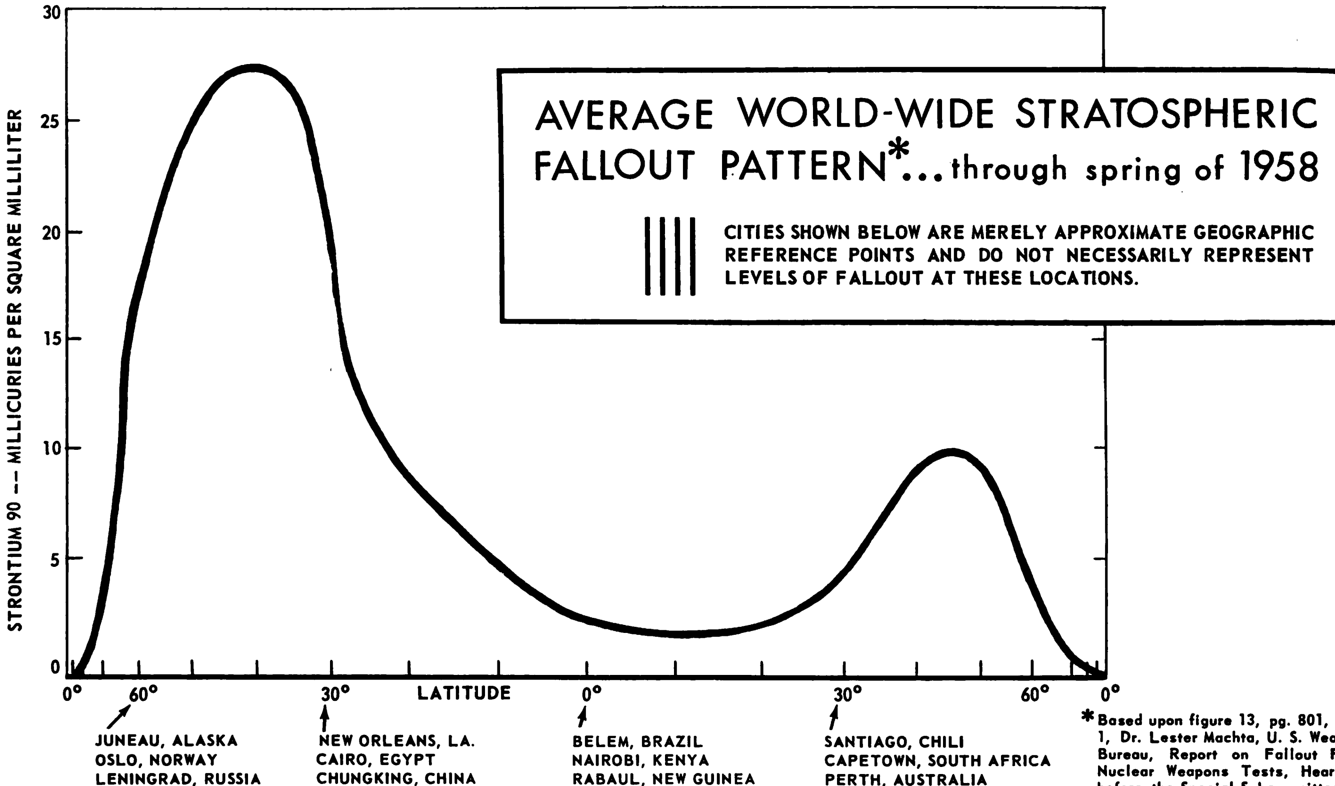


The atmosphere is conventionally divided into two layers as shown in the figure. A lower part, the troposphere, contains our everyday weather. Above the troposphere is the stratosphere in which there are essentially no clouds and little turbulence. The tropopause is the boundary separating the two layers. It varies in height with season and latitude lying mostly in the range from 35,000 to 55,000 feet.

The tropopause suffers a break in the temperate latitude as seen in the figure (points marked J). The break is associated with the jetstream, a strong west-east current of air.

It has been frequently pointed out that the nuclear clouds from less-powerful low-altitude explosions (point A in figure) remain entirely within the troposphere. The radioactivity from these clouds is washed out of the atmosphere quickly, about half being cleansed each month.

In this short period, the radioactive particles do not have time to mix appreciably in a north-south direction while being carried rapidly around the world. More powerful tests or those which are fired at high altitudes (point B in figure), inject their debris into the stratosphere. The absence of rain scavenging and the very slow vertical mixing account for the longer storage of these particles in the stratosphere.... (Dr. Lester Machta, U. S. Weather Bureau, pg. 779, Vol. 1, Report on Fallout From Nuclear Weapons Tests, Hearings before the Special Subcommittee On Radiation of the Joint Committee On Atomic Energy, Congress of the United States, May 5, 6, 7, and 8, 1959.)



*Based upon figure 13, pg. 801, Vol. 1, Dr. Lester Machta, U. S. Weather Bureau, Report on Fallout From Nuclear Weapons Tests, Hearings before the Special Subcommittee On Radiation of the Joint Committee On Atomic Energy, Congress of the United States, May 5,6,7, & 8, 1959.

According to the report of the National Academy of Sciences-National Research Council (The Biological Effects of Atomic Radiation, 1960), research indicates that so far the minimum fallout is in tropic and polar regions, and the maximum between about 40 degrees and 50 degrees of latitude, chiefly in the Northern Hemisphere of the earth. In North America, these latitudes would be north of a line passing through Philadelphia and running north of Kansas City and San Francisco, and south of a line passing through the mouth of the St. Lawrence River and continuing north of the Canadian-United States boundary through Vancouver Island on the west coast. The rate of fallout deposition tends to be heaviest when precipitation is heaviest.

Scientists are studying the patterns of stratospheric fallout that have resulted from weapons tested in previous years. They are not yet sure how quickly the radioactive material reaches the earth from the stratosphere. There is growing evidence that particles blown into the stratosphere in the temperate or arctic zones—such as the tests conducted by Soviet Union—come to earth more quickly than those that result from tests in tropic latitudes—such as United States tests at the Eniwetok site. A large part of fallout from arctic explosions apparently comes to earth within one year. In the case of tropical explosions, mean residence time is believed to be 1 to 5 years

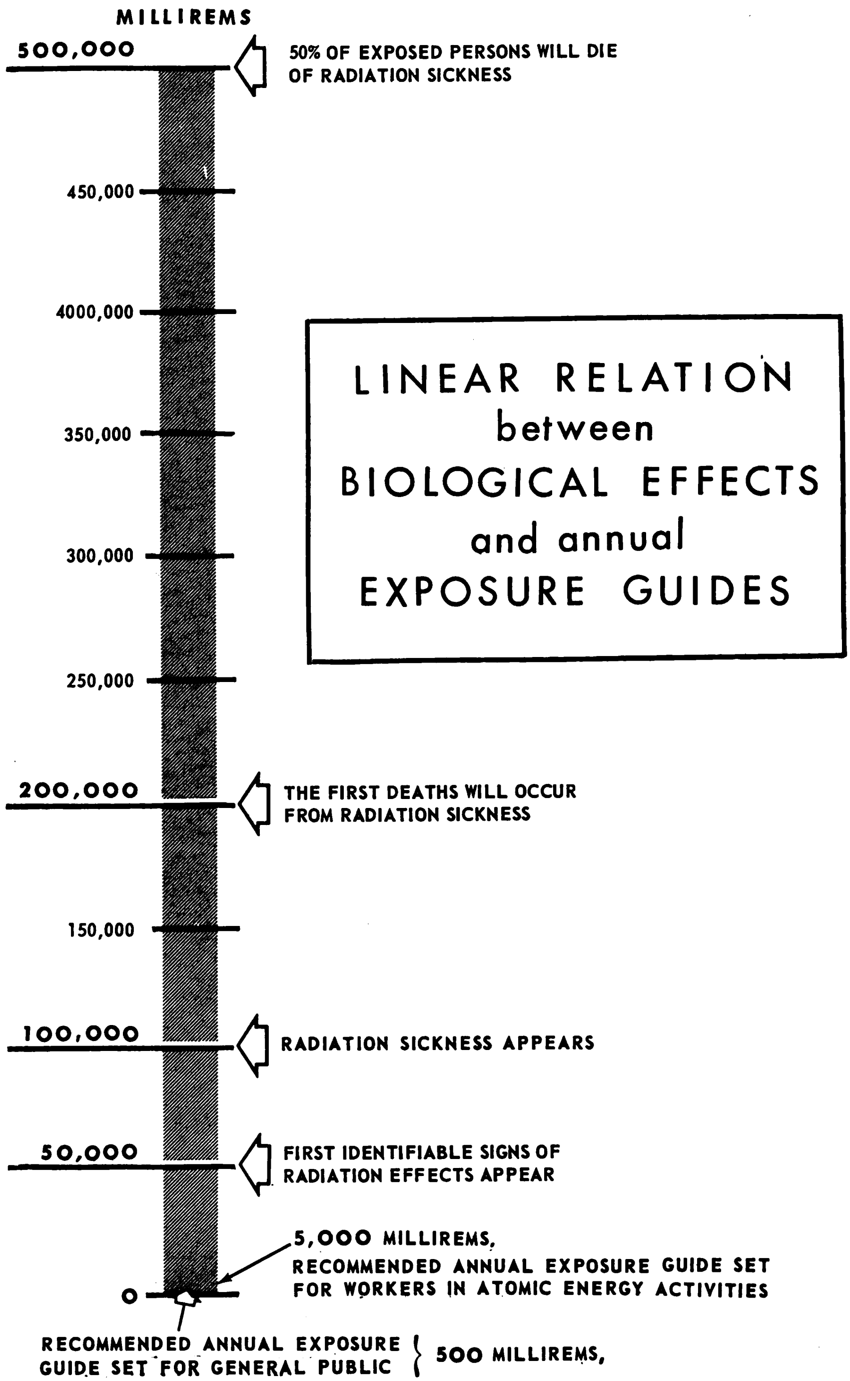
In each latitude, stratospheric fallout tends to be fairly uniform in its broad distribution at the earth's surface. The higher-than-average measurements of fallout in some local areas usually result when rain or snow falls through a radioactive cloud, or air mass, moving through the troposphere from the site of a detonation.

Most of the fallout now in the stratosphere was blown into the upper air before late 1958 when the United States, the Soviet Union, and the United Kingdom separately suspended weapons tests. The United States has conducted no atomic weapons tests since October 31, 1958. The French tests held subsequently released all their radioactive material into the troposphere.

Scientists believe that nuclear devices could be detonated underground in tunnels or natural cavities, or in outer space by means of space vehicles, without placing much, if any, fallout in the earth's atmosphere.

12. *What Does Radiation Do to People?*

The effect that exposure to nuclear radiation may have on anyone depends on several things: What kind of radiation is involved; how much of it a person is exposed to and at what rate; what tissues are irradiated; whether the radiation comes from something outside the body or inside the body and—if inside the body—what particular


MILLIREMS
500,000
50% OF EXPOSED PERSONS WILL DIE OF RADIATION SICKNESS
450,000
4000,000
350,000
300,000
250,000
200,000
THE FIRST DEATHS WILL OCCUR FROM RADIATION SICKNESS
150,000
100,000
RADIATION SICKNESS APPEARS
50,000
FIRST IDENTIFIABLE SIGNS OF RADIATION EFFECTS APPEAR
5,000 MILLIREMS, RECOMMENDED ANNUAL EXPOSURE GUIDE SET FOR WORKERS IN ATOMIC ENERGY ACTIVITIES
0
RECOMMENDED ANNUAL EXPOSURE GUIDE SET FOR GENERAL PUBLIC
500 MILLIREMS,
LINEAR RELATION between BIOLOGICAL EFFECTS and annual EXPOSURE GUIDES

radioisotope is involved, what its chemical nature is, how it got into the body, and where it lodges in the body, and how long it stays there.

Everyone has always been exposed to certain amounts of both external and internal radiation, as the answer to Question No. 5 explains. Inside everyone's body are potassium 40, carbon 14, radium and its decay products, because all these materials are found in drinking water, in the air we breathe, and in foods. As a result of fallout from weapons tests—particularly in the northern hemisphere—people also have in their bodies some cesium 137, strontium 90, and iodine 131 which they have received through their diet.

The radiation that affects people from sources outside the body is penetrating radiation—medical and industrial X-rays, cosmic radiation and gamma rays from various minerals in the earth and from cesium 137, a component of weapons fallout.

Scientists have not been able yet to identify any specific effect that low levels of whole body radiation have upon people. They know that exposure to large amounts of any of the kinds of radiation and radioactive materials may cause impairment—and large amounts of exposure will mean very different levels of radiation depending on the factors listed in the first paragraph of this answer. Taking external radiation as an example, at 50,000 millirems of gamma rays, doctors can detect slight, temporary blood changes. At 100,000 millirems, mild radiation sickness occurs, possibly with nausea and fatigue. At 200,000 to 250,000 millirems, some deaths from radiation may occur; 500,000 millirems would be expected to cause death of about half of any group of people who received that much exposure.

The Federal Radiation Council,[7] established by the President to advise him on radiation matters affecting health, in a report in May 1960, had this to say on biological effects of radiation:

1. Acute doses of radiation may produce immediate or delayed effects, or both.

2. As acute whole body doses increase above 25 rems (25,000 millirems),[8] immediately observable effects increase in severity with dose, beginning from barely detectable changes, to biological signs clearly indicating damage, to death at levels of a few hundred rem (200,000 to 500,000 millirems).[8]

3. Delayed effects produced either by acute irradiation or by chronic irradiation are similar in kind, but the ability of the body to repair radiation damage is usually more effective in the case of chronic than acute irradiation.

4. The delayed effects from radiation are in general indistinguishable from familiar pathological conditions usually present in the population.

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[7] See answer to question No. 18. Full report is given in the Appendix.

[8] Parenthetical information added.

5. Delayed effects include genetic effects (effects transmitted to succeeding generations), increased incidence of tumors, lifespan shortening, and growth and development changes.

6. The child, the infant, and the unborn infant appear to be more sensitive to radiation than the adult.

7. The various organs of the body differ in their sensitivity to radiation.

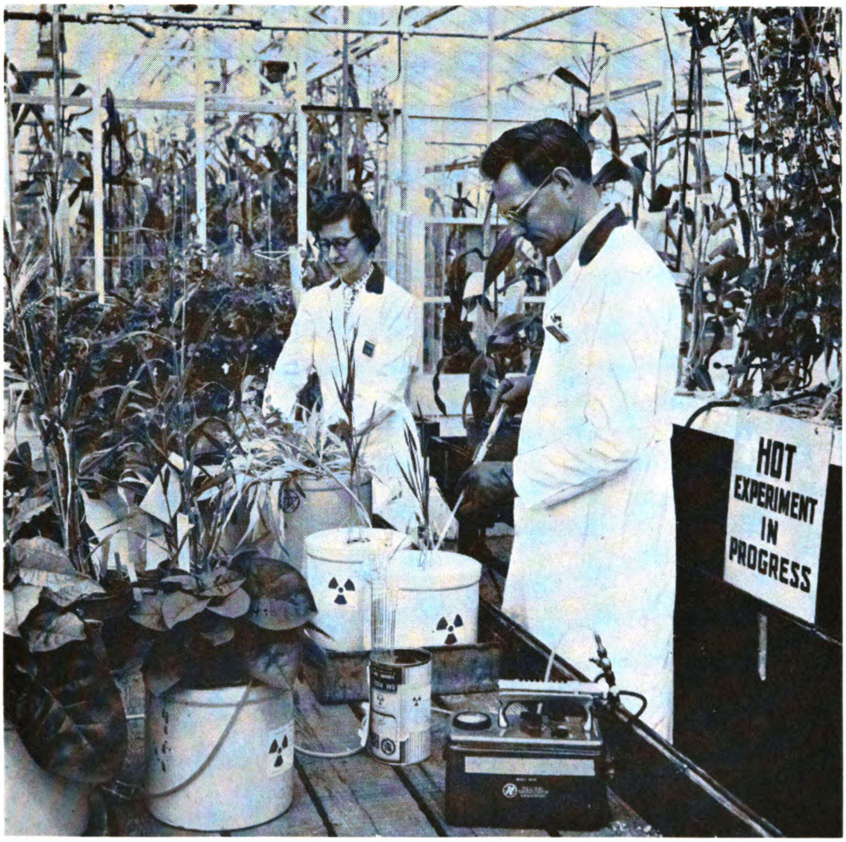
8. Although ionizing radiation can induce genetic and somatic effects (effects on the individual during his lifetime other than genetic effects), the evidence at the present time is insufficient to justify precise conclusions on the nature of the dose-effect relationship at low doses and dose rates. Moreover, the evidence is insufficient to prove either the hypothesis of a "damage threshold" (a point below which no damage occurs) or the hypothesis of "no threshold" in man at low doses.

9. If one assumes a direct linear relation between biological effect and the amount of dose, it then becomes possible to relate very low dose to an assumed biological effect even though it is not detectable. It is generally agreed that the effect that may actually occur will not exceed the amount predicted by this assumption.

Some scientists believe that for a particular biological effect there may be "threshold" radiation exposures—exposures below which this particular effect does not occur in the exposed individual. Others believe that any amount of radiation exposure, no matter how small, has some biological effect. Scientists generally agree, however, that if there is any such effect from small amounts of radiation, the likelihood of its occurrence will be extremely small. This would mean that any individual exposed to a small amount of radiation has only a very slight chance of an impairment resulting. It also would mean that if millions of people are exposed to small amounts of radiation, there is a possibility that impairment will occur in a relatively small number of these people.

No one can be sure, on the basis of present knowledge, whether or not these harmful effects actually will occur. The Federal Radiation Council, however, takes the position that unnecessary radiation exposure is undesirable. If there are reasons for radiation exposure the reason should be balanced against the possible risks involved.

Scientists differ in their judgments about the effect that low levels of radiation may have on human heredity, but most of them believe that the radiation that has always existed in the world is one of the factors—along with certain chemicals and excessive heat—that have caused changes in heredity throughout the history of life on this planet. Changes in heredity—in the physical characteristics passed on through plant seed, or through animal sex cells—have been one of nature's means of accomplishing evolution, the development of different



Increasing Food Crop Yields. Of all the benefits occurring to our daily lives from the applications of atomic energy, the use of radioisotopes in the field of agriculture are the most indirect although providing the most sweeping of all future benefits. Most of the benefits come through new knowledge gained effectively and quickly in a matter of months as against the years formerly required before the radioisotope was utilized in research, or through new strains of plants more quickly tested and put to work. The knowledge when applied to agricultural practice produces improved food supplies. New strains of crop plants may have higher yields or be resistant to damaging diseases or fungi. Whole new fertilization concepts are being developed as a result of atomic research. Since phosphorus is a prime nutritional element for growing plants, radioactive phosphorus can be placed in fertilizers to determine the uptake and use of this element in the plant system. Studies have shown, for example, that among herbacious plants, fertilizers applied as foliar sprays are much more effective upon plant growth than are fertilizers applied to the soil in which the plant is growing. Likewise, through the use of the radioisotope-tagged fertilizers, it has been found that when the fertilizer is placed a few centimeters beneath the seed as it is planted in the soil, the growing plant starts taking up the nutrient much sooner (days) as against the time (weeks) needed when the fertilizer is applied to the soil beside the plant. Other studies have shown that efficient fertilizing methods vary with different types of soil and plants. In the above photo, scientists at the Brookhaven National Laboratory are injecting radioactive phosphorus into a nutrient solution in which barley seedlings are being grown as a part of the studies in nutrient uptake by root systems.

species of plants and animals. It is through such cells that people pass on to their children their physical characteristics: color of hair and eyes and other factors, as well as organic weaknesses or strengths.

Scientists are using radiation today to increase the rate of mutations in plants so as to develop more rapidly some stronger and better-bearing strains of crops for farmers to use. In doing this, scientists use very large amounts of radiation since they are interested in producing the maximum number and variety of changes. Many changes that result are not favorable; some are very favorable.

Where people are concerned, scientists believe that a fraction of the mutations that occur all the time in people is caused by the radiation to which people are always exposed. Scientists have not yet been able to determine what fraction of the mutations is caused by radiation and what by chemical or other agents. Radiation does not produce new kinds of mutations, different from those that are already known to occur; increases in radiation exposure increase the frequency with which mutations occur.

13. *How Does Radiation Cause Damage?*

Scientists are constantly at work trying to find out the exact ways in which radiation causes its effects on living things. Congress annually appropriates some millions of dollars to the Atomic Energy Commission as well as funds to other Federal agencies, to finance the search for knowledge about how to protect people against radiation, and how to treat people who have been accidentally exposed to too much radiation. A good deal has been learned by this scientific research; a great deal more needs to be explained about the exact mechanisms by which radiation affects living things.

Research has shown that exposure to sufficient amounts of nuclear radiation damages or kills the tiny living cells of which our bodies are composed. Radiation does this chiefly by changing the nature of the cells' chemical constituents. Large amounts of radiation also can change the chemical nature of the constituents of body fluids, so that they no longer can fulfill their function, or can even become harmful. Some effects from large amounts of radiation can be detected shortly after exposure, but other effects are delayed, and some may become apparent only after a lapse of considerable time. These effects are called somatic changes since they affect the body. ("Somatic" is from a Greek word that means body.) Male and female reproductive cells also may undergo chemical damage that changes the minute components of those cells that affect heredity.

The atoms of chemical elements in cells or in body fluids—such as hydrogen, oxygen, carbon, and phosphorus—are bound together electrically in functioning groups called *molecules*. A typical effect of radiation is that it knocks loose from one of the atoms one or

several of the electrons outside the atom's nucleus. This changes the electrical balance of the molecule of which the atom is a part, and may break up the molecule or change its character. Radiation also can ionize individual atoms—for example, it could change an atom of hydrogen into a positively charged proton and a negatively charged electron. These ions, as they are called, then could combine with other atoms or molecules in harmful ways.

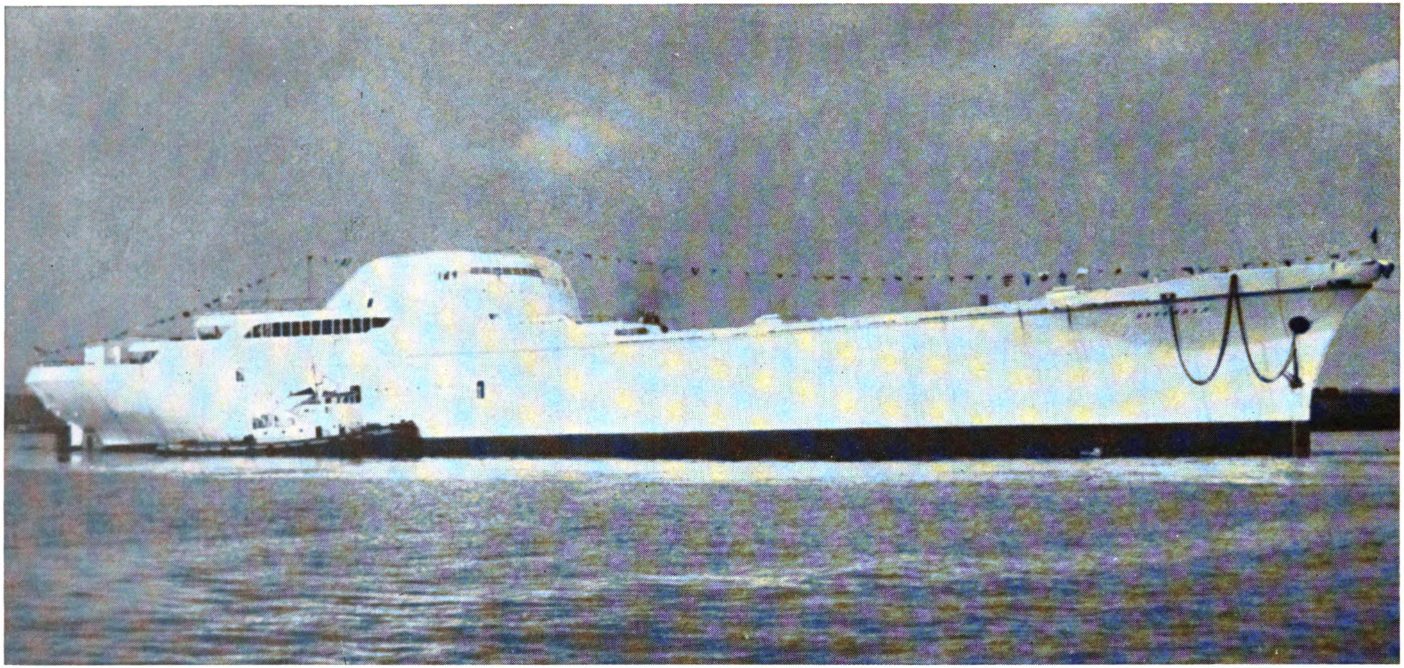
Some such changes as these are taking place in the cells of people's bodies all the time from the natural or manmade radiation, or from chemical causes. In the case of radiation, if the exposure is too heavy, the cells may be damaged so that they no longer can do their normal work in the body, or some cells may be killed. The damage may result directly from radiation, or from the effect of radiation on body fluids. In general, the amount of exposure determines the amount of damage caused.

Cells are always dying in the body and being replaced as part of the natural processes, or from such causes as sicknesses, heat, cold, or absorption of harmful chemicals. The body, and its cells, have great powers of recovery. People become ill from overexposure to radiation only if too many cells are damaged or destroyed at one time, or are destroyed continuously by radioactive material lodged inside the body in sensitive spots over a long period of time.

14. *Can Radiation Injuries Be Cured?*

The body apparently heals itself from whatever injuries to health may occur from exposure to very low levels of radiation. Scientists and doctors have not been able to detect any cumulative effect from the exposures to which people normally are subject. Moderate exposure to external radiation—50,000 millirems, for example—apparently has only a temporary, immediate mild effect from which people recover. Even extremely heavy exposures to specific areas of the body, such as may occur in therapeutic medical use of X-rays—exposures that are severe enough to cause mild radiation sickness—have not, so far as is known, caused any immediate effects from which people do not recover.

The heaviest mass exposure of people that has occurred was in Hiroshima and Nagasaki, Japan during the war. Many of the people severely injured there by very high overexposures apparently made good recoveries. Doctors who examined the injured Japanese were convinced that good medical care, impossible at the time, would have saved many more lives even among those who received heavy exposure. Later, a larger percentage of survivors than normally could have been expected to have the disease developed leukemia (a kind of blood cancer). The Atomic Bomb Casualty Commission of the National Academy of Sciences-National Research Council of



Improving Sea Transportation. The application of atomic energy to propel merchant vessels may assist in solving two problems of coal- and oil-fueled ocean-going vessels—the delays in port while a ship is refueled, and the amount of usable cargo space that must be turned over to fuel storage. In a ship utilizing an atomic reactor as a "furnace" to generate the steam necessary for propulsion, the fuel will be carried within the reactor itself and the ship will be able to travel for several years without refueling. The photo shows the NS *Savannah* ("NS" for nuclear ship) just after she was launched at Camden, N.J., in July 1959. It is the world's first nuclear-powered merchant ship. It has 746,000 cubic feet of cargo space, and can carry 60 passengers at a speed of 21 knots. Outwardly, the only characteristic making the *Savannah* different in appearance from any other passenger-cargo vessel is the absence of a funnel atop the superstructure. The *Savannah* is expected to travel about 300,000 nautical miles, or 3½ years, on the first loading of fuel. It is not anticipated that the *Savannah* will be economically competitive with conventional shipping since it is an experimental vessel. The technology and knowledge learned from her construction and operation, however, may lead eventually to future nuclear-powered merchant ships that can be economically competitive with coal- or oil-fired vessels for specific cargoes on long runs. (U.S. Maritime Administration photo)

the United States was established in 1948 under Commission contract to study the long range medical effects of radiation exposure to the residents of both Hiroshima and Nagasaki. Their studies are continuing among the survivors to determine any other delayed effects caused by the radiation to the body.

The important fact about radiation from outside the body is that it takes quite a large exposure to cause immediate illness. And, as a general rule, only when exposure is very heavy—in the range of 200,000 to 500,000 millirems—is recovery problematical.

When radioactive materials are taken into the body by any means and become lodged there, the injury, the illness, and the long-term effects depend chiefly on the tissues irradiated, and this in turn depends on the kind and amount of radioactive material involved, and on the mode of entry into the body—by breathing, eating, or through a wound. It will also depend, in cases where methods for rapidly removing the material from the body are useful, on how soon treatment is begun. Some radioactive materials are more dangerous than others, quantity for quantity—plutonium is extremely dangerous; so is radium—and the amounts that can cause illness and disease are relatively small. But the amounts of radium which people normally absorb in many drinking waters are not known to have caused illness. In fact, doctors once prescribed for some people spring waters especially rich in radium; they would not do so now, of course, since it has been proved that enough radium deposited in the bones may cause cancer and death. Strontium 90, one of the radioactive substances in fallout, behaves somewhat like radium in the body, but scientists estimate that it takes ten times as much to produce a given effect.

15. *Can Anybody Become Radioactive?*

Everyone in the world has a small amount of radioactivity in his body as a result of breathing air, drinking water, and eating foods, all of which we now know contain small quantities of naturally radioactive substances. In this sense, mankind throughout the ages always has been "radioactive." In recent years, radioactive fallout from tests of atomic weapons has increased slightly the amount of radioactivity in nature, and this has contributed somewhat to the amount of radioactivity which people have in their bodies.

Heavy exposures to X-rays and gamma rays do not make a person detectably radioactive or cause them to become a radiation hazard to others. Radiation is not transmittable, or "catching" between humans, and radioactive materials do not multiply themselves as germs do. From a practical point of view, neutrons are the only radiation occurring in any quantity that can cause some other substance to become radioactive. But neutrons are not emitted by radioactive fallout

or the radioisotopes used in medicine and industry. Except during the fractions of seconds of an atomic explosion, quantities of neutrons are produced only in nuclear reactors—or accidental mixtures of atomic fuels that could simulate a small reactor in operation—and, to a lesser extent, in atom-smashing machines and some small "neutron sources" used chiefly in research.

Hospital patients who have been given radioactive materials internally as part of a medical test or treatment, for a short time have relatively more radioactive material in their bodies than do other people. A small number of persons involved in radiation accidents have taken into their bodies above normal amounts of radioactive materials. However, even if anyone were to ingest so much radioactivity that it impaired his own health, he would not be "radioactive" enough to be dangerous to others.

While radiation itself is not communicable between persons like infectious diseases, a person who has got radioactive material in liquid or dust form on his body or clothing may leave traces of the material on anything he comes in contact with until the contaminant has been brushed or washed off the body or clothing. Prompt, thorough washing usually will remove the radioactive material and the hazard where people have inadvertently picked up such contaminants on their clothes or bodies.

16. *What Is An "Overexposure" to Radiation?*

The Atomic Energy Commission operates its facilities, and regulates licensed uses of nuclear radiation, under standards which require that levels of exposure to workers and to individuals of the public shall be far below those which are known to cause physical impairments.

Under these standards, levels are set for the amount of exposure from sources of external radiation to the entire body, or to parts of the body, normally permitted for atomic energy workers; similarly, "permissible levels" of concentrations in water and air are set for a great number of radioactive materials. Ordinarily, when people speak of "overexposure" they are talking about amounts of radiation in excess of these levels. These standards have been called the maximum permissible exposure (MPE) for individuals and maximum permissible concentrations (MPC) for various types of radioactive materials.

The report of the Federal Radiation Council, mentioned previously, recommended that the term "maximum permissible" not be used any longer, and that the terms radiation protection guide (RPG) and radioactivity concentration guide (RCG) be substituted. The report says that the terms "maximum permissible exposure" and "maximum permissible concentration" are often misunderstood, and that the words "maximum" and "permissible" both have unfortunate

connotations not intended * * * by those who employed them. "Radiation protection guide" actually more clearly states the intentions of the standards. The guides recommended, according to the report, are "well below the level where biological damage has been observed in humans."

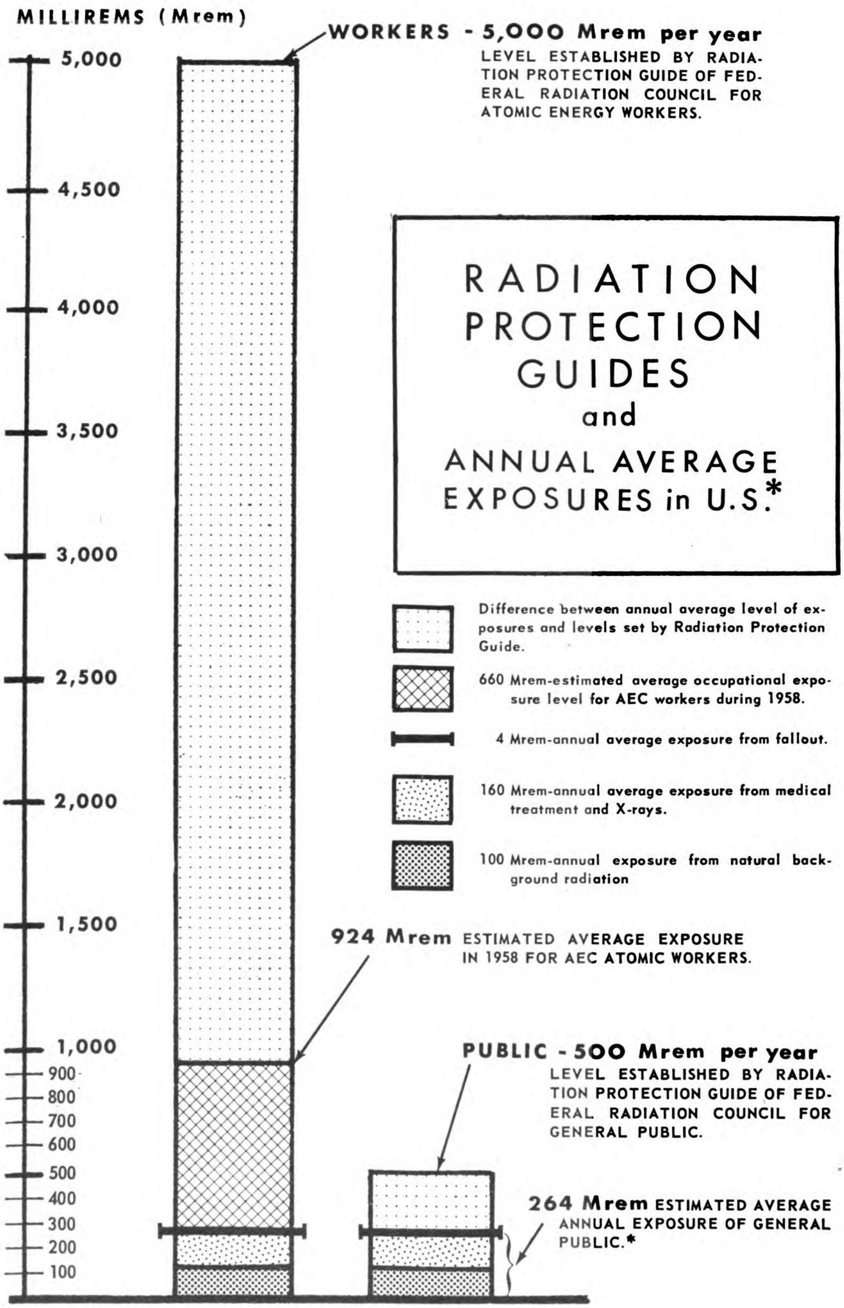
These guides have been established on the basis of the world's half-century of experience with use of radium and X-rays, supplemented by research since 1942 carried on by the Manhattan Engineer District and the Atomic Energy Commission and others, and on the basis of recommendations by the National Committee on Radiation Protection and Measurement, established in 1929, and by the International Commission on Radiological Protection, established in 1928. As a result of experience and research, the biological effects of large amounts of radioactivity are relatively well known because these effects can be observed and measured. Because scientists have not yet been able to observe and measure the biological effects of very low-levels of radiation, these effects must be estimated.

Scientists arrive at these estimates by making an assumption that the effects of radiation will be in direct proportion to the amount of exposure. Thus, at zero-exposure, there will be zero-effects; at specific higher levels, there will be significant biological effects. Between these points—the point at which no effects could occur and the point at which effects are known to occur—the scientists in effect draw a line. At a fraction of the distance up that line, scientists believe they can be reasonably sure that exposure would be unlikely to cause problems for individuals. (See chart.)

The report of the Federal Radiation Council puts it this way:

> If one assumes a direct linear relation between biological effect and the amount of dose, it then becomes possible to relate very low dose to an assumed biological effect even though it is not detectable. It is generally agreed that the effect that may actually occur will not exceed the amount predicted by this assumption.

The standards of radiation exposure, as fixed on the basis of experience and research, are the maximum permissible exposure, or *radiation protection guide*, for external and internal radiation dose; and maximum permissible concentrations, or *radioactivity concentration guide*, for air, water, and food. These concentrations are set at levels consistent with the standards for external radiation. Below these levels, scientists believe that risks associated with specific exposures are sufficiently small, in comparison with other routine risks of existence, to be accepted generally. The original levels set for operations of the Manhattan Engineer District and the Atomic Energy Commission were the "maximums" which were "permitted" for workers' average exposure in normal operation of atomic energy plants.



*Total estimated annual exposure levels including medical usage, background radiation, and fallout.

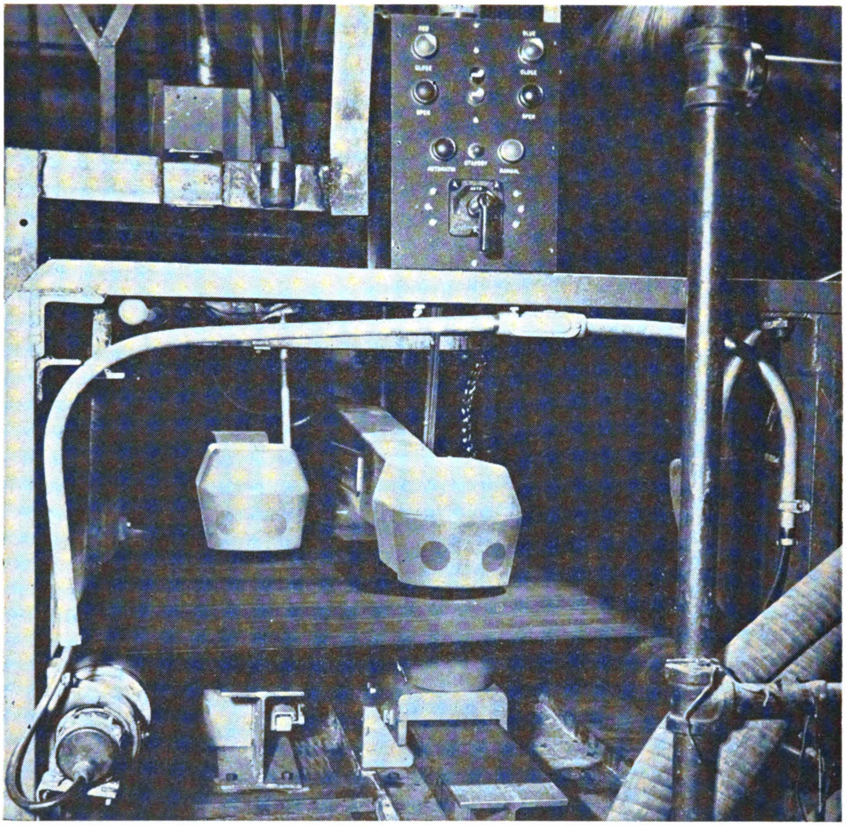
Although the level set for workers in Federal Atomic Energy plants, is higher than for members of the public, the workers' permissible level is still much lower than the level that might be expected to cause some impairment even if continued for a long time. These levels apply to average exposures to the individual.

The actual average levels of exposures experienced by almost all workers throughout atomic energy history are well below the levels established for the months or years of their employment—even if they had some overexposure on occasion. A survey of the Commission's own operations during 1958, for example, showed that 99.7 percent of nearly 66,000 persons working with radiation received less than the annual level of 5,000 millirems recommended as the "guide," and that 90 percent of them received less than one-fifth even of that low level. The remaining 0.3 percent—181 individuals—received more than 5,000 millirems, but their lifetime exposures did not exceed the cumulative level allowable.

Where individuals of the public are concerned, the Commission operates its facilities and regulates its licensed users of radioactivity on the basis that none of the activities shall expose anyone outside plant environs to more than a level generally set up one-tenth of the levels established for workers.

The protection guides thus are not hard and fast boundaries between safe levels and dangerous levels of radiation. Instead, the guides are intended to define specific degrees of low hazard to people exposed to radiation at such average levels over considerable periods of time. A greater exposure implies, not danger as contrasted with safety, but a greater degree of hazard. A lesser exposure implies a smaller degree of hazard. Only zero exposure, which is not possible for anyone on earth because of the existence of natural radiation, would mean no hazard at all. And levels are set on a basis of long-continuing exposure averaged over many years.

Through research, "radiation protection guide" levels have been calculated for scores of radioactive materials. One of those that has been discussed publicly a great deal in recent years is, of course, strontium 90, one of the radioactive substances in fallout. Records of strontium 90 found in various foodstuffs have occasionally shown an excess over the recommended levels. This is an undesirable situation but the extent of hazard involved must be determined by an evaluation of the total amount of these materials that occurs in the diet. The level as established was intended to indicate a level of average consumption that could be continued throughout a lifetime, if necessary. Occasional intake of strontium 90 at levels above the recommended amounts would be less significant than the level averaged over a number of years.



Production of Better Consumer Goods. The various types of radiations given off by atoms are being used in the manufacture of more uniform quality products used in daily life. For instance, the carcass of an automobile tire is made up of layers of rubber-coated fabric cords. Too little rubber permits friction between the cords, too much increases the heat buildup as the tire moves over the road; both reduce tire mileage. Gages utilizing beta particles given off by radioisotopes are now being used to achieve more efficient control over the thickness of the rubber coating applied to the cords, as shown in above photo. The gages (oblong instruments above sheet) measure the amount of radiation passing through the rubber-coated fabricate from the radioisotope source (barely visible below sheet) and automatically control, through electronic devices, the amount of rubber being applied. Radioisotope gages also are used as controls in rolling sheet metal, applying gum to plastic tape, insuring the uniformity of contents in canned goods, controlling the amount of tobacco in cigarettes, measuring ingredients added during paint manufacture, and in hundreds of other manufacturing or processing operations. Experimentation has shown that rubber can be more effectively vulcanized by exposure to gamma irradiation than in the conventional sulfur-heat method. The irradiation causes a direct linkage of the carbon atom chains in the rubber molecules while the sulfur-heat method links the chains through the sulfur atoms—a comparatively "weak" linkage. The nuclear vulcanized rubber shows better resistance to aging, deterioration, abrasion, and wear. This method of rubber vulcanization is still uneconomic and in early stages of experimental development. However, plastic materials which have been made stronger and more durable through gamma irradiation already are on the market. (Photo courtesy of Industrial Nucleonics Corp.)

17. *What Are the "Radiation Protection Guides"?*

The Radiation Protection Guides were approved by the President for the guidance of the Federal agencies on the basis of recommendations made by the Federal Radiation Council in its May 1960 report. In that report, the Council recommended that:

> The following Radiation Protection Guides be adopted for normal peacetime operations:

Type of Exposure	*Condition*	*Dose* (rem)
RADIATION WORKER:		
(*a*) Whole body, head and trunk, active blood-forming organs, gonads, or lens of eye.	Accumulated dose	5 times the number of years beyond 18 at 5,000 mrem a year.
	13 weeks	3 rem (3,000 mrem).
(*b*) Skin of whole body and thyroid.	Year	30 rem (30,000 mrem).
	13 weeks	10 rem (10,000 mrem).
(*c*) Hands and forearms, feet and ankles.	Year	75 rem (75,000 mrem).
	13 weeks	25 rem (25,000 mrem).
(*d*) Bone	Body burden	0.1 microgram of radium 226 or its biological equivalent.
(*e*) Other organs	Year	15 rem (15,000 mrem).
	13 weeks	5 rem (5,000 mrem).
POPULATION:		
(*a*) Individual, whole body	Year	0.5 rem (500 mrem).
(*b*) Average, gonads	30-year	5 rem (5,000 mrem).

Concerning these guides, the report of the Federal Radiation Council stated:

> The fundamental problem in establishing radiation protection guides is to allow as much of the beneficial uses of ionizing radiation as possible while assuring that man is not exposed to undue hazard. To get a true insight into the scope of the problem and the impact of the decisions involved, a review of the benefits and hazards is necessary.
>
> It is important in considering both the benefits and hazards of radiation to appreciate that man has existed throughout his history in a bath of natural radiation. This background radiation, which varies over the earth, provides a partial basis for understanding the effects of radiation on man and serves as an indicator of the ranges of radiation exposure within which the human population has developed and increased.

The Council also made certain basic biological assumptions in establishing the guides. Under this heading, the Council stated:

> There are insufficient data to provide a firm basis for evaluating radiation effects for all types and levels of irradiation. There is

particular uncertainty with respect to the biological effects at very low doses and low-dose rates. It is not prudent therefore to assume that there is a level of radiation exposure below which there is absolute certainty that no effect may occur. This consideration, in addition to the conservative hypothesis of a linear relation between biological effect and the amount of dose, determines our basic approach to the formulation of radiation protection guides.

As an initial recommendation, the Council established a general consideration for all atomic energy activities, declaring that:

There should not be any manmade radiation exposure without the expectation of benefit resulting from such exposure. Activities resulting in manmade radiation exposure should be authorized for useful applications provided the recommendations set forth herein are followed.

The full text of the recommendations is included in the appendix. The second recommendation, after proposing the use of the term "radiation protection guide," defines the guide as "* * * the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as possible."

In the seventh recommendation, the Federal Radiation Council points out that:

The Federal agencies apply these Radiation Protection Guides with judgment and discretion, to assure that reasonable probability is achieved in the attainment of the desired goal of protecting man from the undesirable effects of radiation. The Guides may be exceeded only after the Federal agency having jurisdiction over the matter has carefully considered the reason for doing so in the light of the recommendations of this paper.

The Radiation Protection Guides provide a general framework for the radiation protection requirements. It is expected that each Federal agency, by virtue of its immediate knowledge of its operating problems, will use these guides as a basis upon which to develop detailed standards tailored to meet its particular requirements. The Council will follow the activities of the Federal agencies in this area and will promote the necessary coordination to achieve an effective Federal program.

The Council's recommendations also made the following points in relation to the Radiation Protection Guides:

1. For the individual in the population, the basic guide for annual whole body dose is 0.5 rem (500 mrem). This guide applies when the individual whole body doses are known. As an operational technique, where the individual whole body doses are not

known, a suitable sample of the exposed population should be developed whose protection guide for annual whole body dose will be 0.17 rem (170 mrem) per capita per year. It is emphasized that this is an operational technique which should be modified to meet special situations.

2. Considerations of population genetics impose a per capita dose limitation for the gonads of 5 rems (5,000 mrems) in 30 years. The operational mechanism described above for the annual individual whole body dose of 0.5 rem (500 mrem) is likely in the immediate future to assure that the gonadal exposure guide (5 rem in 30 years) is not exceeded.

3. These guides do not differ substantially from certain other recommendations such as those made by the National Committee on Radiation Protection and Measurements, the National Academy of Sciences, and the International Commission on Radiological Protection.

4. The term "maximum permissible dose" is used by the National Commission on Radiation Protection (NCRP) and the International Commission on Radiological Protection (ICRP). However, this term is often misunderstood. The words "maximum" and "permissible" both have unfortunate connotations not intended by either the NCRP or the ICRP.

5. There can be no single permissible or acceptable level of exposure without regard to the reason for permitting the exposure. It should be general practice to reduce exposure to radiation, and positive effort should be carried out to fulfill the sense of these recommendations. It is basic that exposure to radiation should result from a real determination of its necessity.

6. There can be different Radiation Protection Guides with different numerical values, depending upon circumstances. The Guides herein recommended are appropriate for normal peacetime operations.

7. These Guides are not intended to apply to radiation exposure resulting from natural background or the purposeful exposure of patients by practitioners of the healing arts.

8. It is recognized that our present scientific knowledge does not provide a firm foundation within a factor of two or three for selection of any particular numerical value in preference to another value. It should be recognized that the Radiation Protection Guides recommended in this paper are well below the level where biological damage has been observed in humans.

18. *How Is The Public Protected Against Radiation?*

The Federal Government has the responsibility for protecting people against radiation originating from atomic energy activities. Under a law passed in 1959, the individual States will share in this responsibility when they wish to, and when they have developed the technical staffs and know-how. The Federal Government has no general regulatory responsibility to control the use of X-rays or of radium.

Within the Federal Government, the Federal Radiation Council was established during 1959 to recommend to the President the standards that should be established for control of radiation. Its first report has been quoted previously, and is given in full in the appendix. The Federal Radiation Council includes the Secretaries of Defense, Commerce, Labor, and of Health, Education, and Welfare, the Chairman of the Atomic Energy Commission, and others as designated by the President. The Assistant to the President for Science and Technology participates. The Atomic Energy Commission is empowered to set standards for its operations and for licenses and does so on the basis of its own experience and on the recommendations of the Federal Radiation Council, and of the National Committee on Radiation Protection and Measurements, which comprises notable scientists, physicians, and Government officials experienced in the use of radiation. The National Committee cooperates in this work with the International Commission on Radiological Protection. The Secretary of Health, Education and Welfare, under whom is the United States Public Health Service, was designated in 1959 as chairman of the Federal Radiation Council.

As described in the answer to the preceding question, the Atomic Energy Commission accomplishes protection of the public primarily by establishing and enforcing standards for handling radiation and for operations involving radiation.

APPENDIX

THE WHITE HOUSE

MAY 17, 1960

THE WHITE HOUSE TODAY MADE PUBLIC THE FOLLOWING MEMORANDUM TO THE PRESIDENT FROM THE CHAIRMAN OF THE FEDERAL RADIATION COUNCIL. THE PRESIDENT APPROVED RECOMMENDATIONS NUMBERED 1 THROUGH 7 OF THE MEMORANDUM FOR THE GUIDANCE OF FEDERAL AGENCIES

MEMORANDUM FOR THE PRESIDENT

SUBJECT: Radiation Protection Guidance for Federal Agencies

Pursuant to Executive Order 10831 and P.L. 86–373 the Federal Radiation Council has made a study of the hazards and use of radiation. We herewith transmit our first report to you concerning our findings and our recommendations for the guidance of Federal agencies in the conduct of their radiation protection activities.

It is the statutory responsibility of the Council to "* * * advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all Federal agencies in the formulation of radiation standards and in the establishment and execution of programs of cooperation with States * * *"

Fundamentally, setting basic radiation protection standards involves passing judgment on the extent of the possible health hazard society is willing to accept in order to realize the known benefits of radiation. It involves inevitably a balancing between total health protection, which might require foregoing any activities increasing exposure to radiation, and the vigorous promotion of the use of radiation and atomic energy in order to achieve optimum benefits.

The Federal Radiation Council has reviewed available knowledge on radiation effects and consulted with scientists within and outside the Government. Each member has also examined the guidance recommended in this memorandum in light of his statutory responsibilities. Although the guidance does not cover all phases of radiation protection, such as internal emitters, we find that the guidance which we recommend that you provide for the use of Federal agencies gives appropriate consideration to the requirements of health protection and the beneficial uses of radiation and atomic energy. Our further findings and recommendations follow.

Discussion

The fundamental problem in establishing radiation protection guides is to allow as much of the beneficial uses of ionizing radiation as possible while assuring that man is not exposed to undue hazard. To get a true insight into the scope of the problem and the impact of the decisions involved, a review of the benefits and the hazards is necessary.

It is important in considering both the benefits and hazards of radiation to appreciate that man has existed throughout his history in a bath of natural radia-

tion. This background radiation, which varies over the earth, provides a partial basis for understanding the effects of radiation on man and serves as an indicator of the ranges of radiation exposures within which the human population has developed and increased.

The Benefits of Ionizing Radiation

Radiation properly controlled is a boon to mankind. It has been of inestimable value in the diagnosis and treatment of diseases. It can provide sources of energy greater than any the world has yet had available. In industry, it is used as a tool to measure thickness, quantity or quality, to discover hidden flaws, to trace liquid flow, and for other purposes. So many research uses for ionizing radiation have been found that scientists in many diverse fields now rank radiation with the microscope in value as a working tool.

The Hazards of Ionizing Radiation

Ionizing radiation involves health hazards just as do many other useful tools. Scientific findings concerning the biological effects of radiation of most immediate interest to the establishment of radiation protection standards are the following:

1. Acute doses of radiation may produce immediate or delayed effects, or both.
2. As acute whole body doses increase above approximately 25 rems (units of radiation dose), immediately observable effects increase in severity with dose, beginning from barely detectable changes, to biological signs clearly indicating damage, to death at levels of a few hundred rems.
3. Delayed effects produced either by acute irradiation or by chronic irradiation are similar in kind, but the ability of the body to repair radiation damage is usually more effective in the case of chronic than acute irradiation.
4. The delayed effects from radiation are in general indistinguishable from familiar pathological conditions usually present in the population.
5. Delayed effects include genetic effects (effects transmitted to succeeding generations), increased incidence of tumors, lifespan shortening, and growth and development changes.
6. The child, the infant, and the unborn infant appear to be more sensitive to radiation than the adult.
7. The various organs of the body differ in their sensitivity to radiation.
8. Although ionizing radiation can induce genetic and somatic effects (effects on the individual during his lifetime other than genetic effects), the evidence at the present time is insufficient to justify precise conclusions on the nature of the dose-effect relationship at low doses and dose rates. Moreover, the evidence is insufficient to prove either the hypothesis of a "damage threshold" (a point below which no damage occurs) or the hypothesis of "no threshold" in man at low doses.
9. If one assumes a direct linear relation between biological effect and the amount of dose, it then becomes possible to relate very low dose to an assumed biological effect even though it is not detectable. It is generally agreed that the effect that may actually occur will not exceed the amount predicted by this assumption.

Basic Biological Assumptions

There are insufficient data to provide a firm basis for evaluating radiation effects for all types and levels of irradiation. There is particular uncertainty with respect to the biological effects at very low doses and low-dose rates. It is

not prudent therefore to assume that there is a level of radiation exposure below which there is absolute certainty that no effect may occur. This consideration, in addition to the adoption of the conservative hypothesis of a linear relation between biological effect and the amount of dose, determines our basic approach to the formulation of radiation protection guides.

The lack of adequate scientific information makes it urgent that additional research be undertaken and new data developed to provide a firmer basis for evaluating biological risk. Appropriate member agencies of the Federal Radiation Council are sponsoring and encouraging research in these areas.

Recommendations

In view of the findings summarized above the following recommendations are made:

It is recommended that:

1. There should not be any manmade radiation exposure without the expectation of benefit resulting from such exposure. Activities resulting in manmade radiation exposure should be authorized for useful applications provided the recommendations set forth herein are followed.

It is recommended that:

2. The term "Radiation Protection Guide" be adopted for Federal use. This term is defined as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable.

It is recommended that:

3. The following Radiation Protection Guides be adopted for normal peacetime operations:

Type of exposure	*Condition*	*Dose (rem)*
Radiation Worker:		
(*a*) Whole body, head and trunk, active blood forming organs, gonads, or lens of eye.	Accumulated dose	5 times the number of years beyond age 18.
	13 weeks	3.
(*b*) Skin of whole body and thyroid.	Year	30.
	13 weeks	10.
(*c*) Hands and forearms, feet and ankles.	Year	75.
	13 weeks	25.
(*d*) Bone	Body burden	0.1 microgram of radium-226 or its biological equivalent.
(*e*) Other organs	Year	15.
	13 weeks	5.
Population:		
(*a*) Individual	Year	0.5 (whole body).
(*b*) Average	30 year	5 (gonads).

The following points are made in relation to the Radiation Protection Guides herein provided:

(1) For the individual in the population, the basic Guide for annual whole body dose is 0.5 rem. This Guide applies when the individual whole body doses are known. As an operational technique, where the individual whole body doses are not known, a suitable sample of the exposed population should be developed whose protection guide for annual whole body dose will be 0.17 rem per capita per year. It is emphasized that this is an operational technique which should be modified to meet special situations.

(2) Considerations of population genetics impose a per capita dose limitation for the gonads of 5 rems in 30 years. The operational mechanism described above for the annual individual whole body dose of 0.5 rem is likely in the immediate future to assure that the gonadal exposure Guide (5 rem in 30 years) is not exceeded.

(3) These Guides do not differ substantially from certain other recommendations such as those made by the National Committee on Radiation Protection and Measurements, the National Academy of Sciences, and the International Commission on Radiological Protection.

(4) The term "maximum permissible dose" is used by the National Committee on Radiation Protection (NCRP) and the International Commission on Radiological Protection (ICRP). However, this term is often misunderstood. The words "maximum" and "permissible" both have unfortunate connotations not intended by either the NCRP or the ICRP.

(5) There can be no single permissible or acceptable level of exposure without regard to the reason for permitting the exposure. It should be general practice to reduce exposure to radiation, and positive effort should be carried out to fulfill the sense of these recommendations. It is basic that exposure to radiation should result from a real determination of its necessity.

(6) There can be different Radiation Protection Guides with different numerical values, depending upon the circumstances. The Guides herein recommended are appropriate for normal peacetime operations.

(7) These Guides are not intended to apply to radiation exposure resulting from natural background or the purposeful exposure of patients by practitioners of the healing arts.

(8) It is recognized that our present scientific knowledge does not provide a firm foundation within a factor of two or three for selection of any particular numerical value in preference to another value. It should be recognized that the Radiation Protection Guides recommended in this paper are well below the level where biological damage has been observed in humans.

It is recommended that:

4. Current protection guides used by the agencies be continued on an interim basis for organ doses to the population.

Recommendations are not made concerning the Radiation Protection Guides for individual organ doses to the population, other than the gonads. Unfortunately, the complexities of establishing guides applicable to radiation exposure of all body organs preclude the Council from making recommendations concerning them at this time. However, current protection guides used by the agencies appear appropriate on an interim basis.

It is recommended that:

5. The term "Radioactivity Concentration Guide" be adopted for Federal use. This term is defined as the concentration of radioactivity in the environment

which is determined to result in whole body or organ doses equal to the Radiation Protection Guide.

Within this definition, Radioactivity Concentration Guides can be determined after the Radiation Protection Guides are decided upon. Any given Radioactivity Concentration Guide is applicable only for the circumstances under which the use of its corresponding Radiation Protection Guide is appropriate.

It is recommended that:

6. The Federal agencies, as an interim measure, use radioactivity concentration guides which are consistent with the recommended Radiation Protection Guides. Where no Radiation Protection Guides are provided, Federal agencies continue present practices.

No specific numerical recommendations for Radioactivity Concentration Guides are provided at this time. However, concentration guides now used by the agencies appear appropriate on an interim basis. Where appropriate radioactivity concentration guides are not available, and where Radiation Protection Guides for specific organs are provided herein, the latter Guides can be used by the Federal agencies as a starting point for the derivation of radioactivity concentration guides applicable to their particular problems. The Federal Radiation Council has also initiated action directed towards the development of additional Guides for radiation protection.

It is recommended that:

7. The Federal agencies apply these Radiation Protection Guides with judgment and discretion, to assure that reasonable probability is achieved in the attainment of the desired goal of protecting man from the undesirable effects of radiation. The Guides may be exceeded only after the Federal agency having jurisdiction over the matter has carefully considered the reason for doing so in light of the recommendations in this paper.

The Radiation Protection Guides provide a general framework for the radiation protection requirements. It is expected that each Federal agency, by virtue of its immediate knowledge of its operating problems, will use these Guides as a basis upon which to develop detailed standards tailored to meet its particular requirements. The Council will follow the activities of the Federal agencies in this area and will promote the necessary coordination to achieve an effective Federal program.

If the foregoing recommendations are approved by you for the guidance of Federal agencies in the conduct of their radiation protection activities, it is further recommended that this memorandum be published in the Federal Register.

ARTHUR S. FLEMMING,
Chairman, Federal Radiation Council.

The recommendations numbered "1" through "7" contained in the above memorandum are approved for the guidance of Federal agencies, and the memorandum shall be published in the Federal Register.

DWIGHT D. EISENHOWER,
May 13, 1960.

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